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Attainment Status and PSD (Prevention of Significant Deterioration) Analyses for Port Angeles, Washington

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16. ABSTRACT

This report describes a dispersion model analysis of the air quality impact of emissions from the existing and proposed sulfur dioxide (SO_2) sources in the Port Angeles, Washington area. The existing SO_2 sources are the Crown Zellerbach and ITT Rayonier Pulp Mills and the proposed sources are the tankers involved in the Northern Tier Pipeline Company (NTPC) project. The specific objectives of the study described in this report were to: (1) determine, for the existing sources, the attainment status of the Port Angeles area with respect to the National Ambient Air Quality Standards (NAAQS) for SO_2; (2) evaluate the effects of various emission control strategies for the existing sources if Port Angeles is found to be a non-attainment area for the NAAQS; (3) determine Prevention of Significant Deterioration (PSD) Increment consumption of the proposed NTPC sources in Class I and Class II PSD areas; and, (4) determine if the proposed NTPC sources will cause any area that currently is an attainment area for the NAAQS to become a non-attainment area.

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by

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EXECUTIVE SUMMARY

INTRODUCTION

This report describes a dispersion model analysis of the air quality impact of emissions from the existing and proposed sulfur dioxide (SO_2) sources in the Port Angeles, Washington area. The existing SO_2 sources are the Crown Zellerbach and ITT Rayonier Pulp Mills and the proposed sources are the tankers involved in the Northern Tier Pipeline Company (NTPC) project. The specific objectives of the study described in this report were to: (1) determine, for the existing sources, the attainment status of the Port Angeles area with respect to the National Ambient Air Quality Standards (NAAQS) for SO_2; (2) evaluate the effects of various emission control strategies for the existing sources if Port Angeles is found to be a non-attainment area for the NAAQS; (3) determine Prevention of Significant Deterioration (PSD) Increment consumption of the proposed NTPC sources in Class I and Class II PSD areas; and, (4) determine if the proposed NTPC sources will cause any area that currently is an attainment area for the NAAQS to become a non-attainment area. The NAAQS and the Class I and Class II PSD Increments for SO_2 are listed in Table I. The State of Washington 1-hour ambient air quality standard of 0.40 parts per million (ppm), not to be exceeded at any given point more than once per year, is also considered in this report.

SUPPLEMENTARY INFORMATION

As indicated by Table I, a short-term NAAQS or PSD Increment is violated at a given point during the second short-term period in a year with a short-term concentration above the corresponding NAAQS or PSD Increment. In general, the same definition of a violation of a short-term NAAQS or PSD Increment is applied to the results of dispersion model

TABLE I

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) AND CLASS I AND CLASS II PREVENTION OF SIGNIFICANT DETERIORATION (PSD) INCREMENTS FOR SULFUR DIOXIDE (SO_2)

Averaging Time	NAAQS ($\mu g/m^3$)		PSD Increments ($\mu g/m^3$)	
	Primary	Secondary	Class I	Class II
3 Hours*	-	1,300	25	512
24 Hours*	365	-	5	91
Annual	80	-	2	20

*The 3-hour and 24-hour NAAQS and PSD Increments may be exceeded at any given point once per year.

calculations. For example, the second-highest 24-hour average SO_2 concentration calculated for a receptor during a year normally is used to assess the compliance of the receptor with the 24-hour NAAQS for SO_2. However, if the U. S. Environmental Protection Agency (EPA) Regional Administrator identifies inadequacies in the data available for input to the dispersion model (for example, poorly defined emissions data or an insufficient period of record of meteorological data), the Administrator may specify that the highest rather than the highest of the second-highest short-term concentrations calculated for all receptors be used to evaluate compliance with the short-term NAAQS and PSD Increments. As of 18 November 1980, the Administrator of EPA Region 10 had not made any determination about the adequacy of the emissions and meteorological data available for the Port Angeles area. Consequently, this report considers both the highest and the highest, second-highest calculated short-term concentrations in evaluating compliance with the short-term NAAQS and PSD Increments.

We point out that two different units for SO_2 concentrations are used in this report. In the analyses of air quality data and the comparisons of concurrent calculated and observed SO_2 concentrations, concentrations are expressed in parts per million (ppm) because the observed concentrations are recorded and reported in these units. In the analyses of attainment status, PSD Increments and control strategies, concentrations are expressed in micrograms per cubic meter because these units are generally used for regulatory purposes.

CALCULATION PROCEDURES

The source data for the existing and proposed SO_2 sources were provided by EPA Region 10. The dispersion model calculations were performed using the Cramer, et al. (1975) complex terrain dispersion model, which is implemented by the SHORTZ and LONGZ computer codes. This model has worked well in a similar application in the Puget Sound area (Cramer, et al., 1976) and, as discussed below, was also tested in the Port Angeles area as part of this study. The meteorological inputs to the SHORTZ and LONGZ programs were developed following the general guidance given by Bjorklund and Bowers (1979). On the basis of our meteorological site survey of the Port Angeles area and our analyses of the available meteorological and air quality data, we selected the Ediz Hook 10-meter tower wind data as most likely to be representative of the winds affecting the initial dilution and transport of emissions from the existing and proposed sources, all of which are located along the shoreline or in Port Angeles Harbor. The Ediz Hook wind-speed data and concurrent Whidbey Island cloud-cover data were used to assign the Pasquill stabiltiy category to each hour during the period 15 August 1978 to 15 August 1979 following the Turner (1964) stability classification scheme. Other meteorological inputs used in the dispersion model calculations were selected to be representative of the characteristics of the marine air mass over the harbor and shoreline. Specifically, the Cramer, et al. (1975) rural turbulent intensities were assigned to each hour on the basis of the Pasquill stability category and, for each hour, the wind-profile exponent was set equal to 0.10 and the vertical potential temperature gradient was set equal to the moist adiabatic value of 0.003 degrees Kelvin per meter. Also, in the absence of any other mixing depth estimates for Port Angeles, we used in the model calculations the hourly mixing depths calculated by NTPC (1980) from Quillayute, Washington upper-air data and Port Angeles wind-speed data following the procedures described by Benkley and Schulman (1979).

SUMMARY OF THE RESULTS OF MODEL TESTING

The highest measured SO_2 concentrations in the Port Angeles area occur at the Third & Chestnut and Fourth & Baker monitors which are located east-southeast of the largest existing SO_2 source, the ITT Rayonier Mill. Because of time and level-of-effort constraints, model testing was restricted to a detailed examination of 20 hours with relatively high observed concentrations at both monitors. The following criteria were used to select these 20 hours:

- An observed 1-hour SO_2 concentration greater than or equal to 0.20 ppm at one of the two monitors and a concurrent observed concentration greater than or equal to 0.05 ppm at the second monitor
- Availability of complete meteorological data for the two meteorological towers operated by NTPC during the period 15 August 1978 to 15 August 1979
- Operation of a minimum of three of the six ITT sources for which emissions data were available

The third selection criterion was based on the fact that all of the ITT sources were to be included in the attainment status analysis, and we wished to test the performance of the short-term (SHORTZ) model under conditions approximating the operating conditions for the attainment status calculations.

After the selection of the 20 hours for model testing, we learned that the black liquor holding pond at the ITT Mill is an important source of SO_2 emissions which may have a significant impact on ambient air quality in the vicinity of the mill (Fenske, 1980). Inspection of the Ediz Hook wind directions for the 20 hours selected for model testing indicated that any emissions from the holding pond probably did not contribute to the concentrations measured during these hours at the Third & Chestnut monitor, but most probably did contribute to the concurrent concentrations measured at the Fourth & Baker monitor. Because the emissions from the holding pond are unquantified, we calculated centerline concentrations at the Third & Chestnut monitor to test the performance of the SHORTZ model for the stack emissions. Assuming a "perfect model" and representative model inputs as well as air quality observations, the calculated centerline concentration plus the "background" concentration should be greater than or equal to the corresponding observed concentration for each hour. Also, the mean ratio (MR) of calculated centerline (plus "background")to observed concentrations should be approximately equal to 1.75, as explained in Section 3 in the main body of the report. (We define "background" as ambient SO_2 concentrations attributable to emissions from existing sources other than the ITT and Crown Zellerbach Mills.) The MR is given by the sum of the calculated centerline concentrations (plus background), divided by the sum of the observed concentrations. Estimates of the hourly SO_2 background concentration, which were generally less than 0.01 ppm, were obtained from concurrent measurements made at the SO_2 monitor located at the Olympic National Park Visitor Center.

Table II compares the calculated centerline and corresponding observed 1-hour SO_2 concentrations at the Third & Chestnut monitor for the 20 hours selected for model testing. With the exception of Cases 10, 11 and 15, all of the calculated centerline concentrations are greater than or equal to the corresponding observed concentrations. According to the Washington DOE (Fenske, 1980), the pollution control system used by the ITT Mill during the period containing the hours selected for model testing was unreliable, and SO_2 emissions from several of the low-level sources at the mill could have been higher than estimated by ITT without ITT's knowledge. Thus, the three cases in which the calculated centerline concentrations plus background are less than the corresponding observed concentrations are possibly explained by the use of emission rates in the model calculations which are less than the actual emission rates during these hours. The MR of 1.85 is in close agreement with the expected value of 1.75 and indicates that, on the average, the model is accurate to within about 10 percent. This result is consistent with our previous experience in testing the model in similar applications (Cramer, et al., 1975; Cramer and Bowers, 1976; and Cramer, et al., 1976). We point out that the contribution of emissions from the Crown Zellerbach Mill to the calculated concentrations in Table II is less than 0.01 ppm in every case.

TABLE II

COMPARISON OF CALCULATED CENTERLINE AND CORRESPONDING OBSERVED 1-HOUR SO_2 CONCENTRATION AT THIRD & CHESTNUT

Case	Concentration (ppm)		Ratio of Calculated and Observed Concentrations
	Observed	Calculated Centerline*	
1	0.11	0.32	2.91
2	0.27	0.32	1.19
3	0.23	0.30	1.30
4	0.13	0.22	1.69
5	0.13	0.18	1.38
6	0.09	0.35	3.89
7	0.08	0.37	4.63
8	0.07	0.37	5.29
9	0.13	0.56	4.31
10	0.33	0.23	0.70
11	0.19	0.17	0.89
12	0.20	0.36	1.80
13	0.19	0.43	2.26
14	0.30	0.30	1.00
15	0.47	0.44	0.94
16	0.17	0.37	2.18
17	0.12	0.37	3.08
18	0.06	0.36	6.00
19	0.15	0.32	2.13
20	0.13	0.24	1.85
		Mean Ratio (MR)	1.85

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*The calculated concentrations include background (the concurrent SO_2 concentrations measured at the Visitor Center).

RESULTS OF THE ATTAINMENT STATUS ANALYSIS

The calculated maximum short-term and annual average ground-level SO_2 concentrations produced by emissions from the ITT Rayonier and Crown Zellerbach Mills are listed in Tables III and IV, respectively. Tables III and IV also give background SO_2 concentration estimates which are based on concurrent SO_2 concentrations measured upwind of the existing sources, except that the minimum background is set equal to the threshold and accuracy of the SO_2 monitors of about 13 micrograms per cubic meter.

Inspection of Tables III and IV shows that the highest short-term and annual average SO_2 concentrations calculated for the combined stack emissions from the existing sources in the Port Angeles area are almost entirely determined by emissions from the ITT Mill. Comparison of Tables I and III shows that the calculated maximum annual average concentration is below the annual NAAQS. However, 3-hour average concentrations above the 3-hour NAAQS are calculated to occur once per year in the area east-southeast of the ITT Mill and 24-hour average concentrations above the 24-hour NAAQS are calculated to occur once per year in the area southwest of the ITT Mill and four times per year in the area east-southeast of the ITT Mill. (The maximum 24-hour concentration given in Table III is calculated to occur 0.4 kilometers southwest of the ITT Mill.) Thus, if any calculated short-term concentration above the corresponding NAAQS is defined as a violation of the NAAQS, non-attainment areas for the 24-hour NAAQS are located southwest and east-southeast of the ITT Mill and a non-attainment area for the 3-hour NAAQS is located east-southeast of the ITT Mill. Figure I(a) shows the areas within which 24-hour average concentrations above the 24-hour NAAQS are calculated to occur one or more times per year. The area within which 3-hour average concentrations above the 3-hour NAAQS are calculated to occur once per year is entirely contained within the non-attainment area for the 24-hour NAAQS that is east-southeast of the ITT Mill. If it is assumed that a short-term NAAQS is violated at a given point during the second short-term period

TABLE III

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM SHORT-TERM AND ANNUAL AVERAGE SO_2 CONCENTRATIONS CALCULATED IN THE VICINITY OF THE ITT RAYONIER MILL

Source	Concentration (μg/m^3)			
	1-Hour	3-Hour	24-Hour	Annual
ITT Recovery Furnace	4	33	0	0.94
ITT West and East Vents (Acid Plant)	734	457	171	17.51
ITT North Bleach Vent	14	9	5	0.39
ITT South Bleach Vent	50	31	18	1.45
ITT Power Boiler No. 4	877	493	367	7.19
ITT Power Boiler No. 5	537	384	19	3.11
ITT HF Boiler No. 5	18	17	0	1.40
ITT Rayonier Total	2,234	1,424	581	31.99
Crown Zellerbach Total *	3	5	12	0.48
Background Estimate	13	13	13	13.00
Total for Existing Sources	2,250	1,442	606	45.47

*Contribution of emissions from the Crown Zellerbach Mill to the total concentration calculated for the existing sources at the point of maximum impact for the ITT Mill.

TABLE IV

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM SHORT-TERM AND ANNUAL AVERAGE SO_2 CONCENTRATIONS CALCULATED IN THE VICINITY OF THE CROWN ZELLERBACH MILL

Source	Concentration ($\mu g/m^3$)			
	1-Hour	3-Hour	24-Hour	Annual
Crown Zellerbach HF Boiler No. 8	470	369	236	1.44
Crown Zellerbach Package Boiler	122	92	55	5.25
Crown Zellerbach Total	592	461	292	6.69
ITT Rayonier Total*	0	0	0	2.07
Background Estimate	236	170	13	13.00
Total for Existing Sources	828	631	305	21.75

*Contribution of emissions from the ITT Rayonier Mill to the total concentration calculated for the existing sources at the point of maximum impact for the Crown Zellerbach Mill.

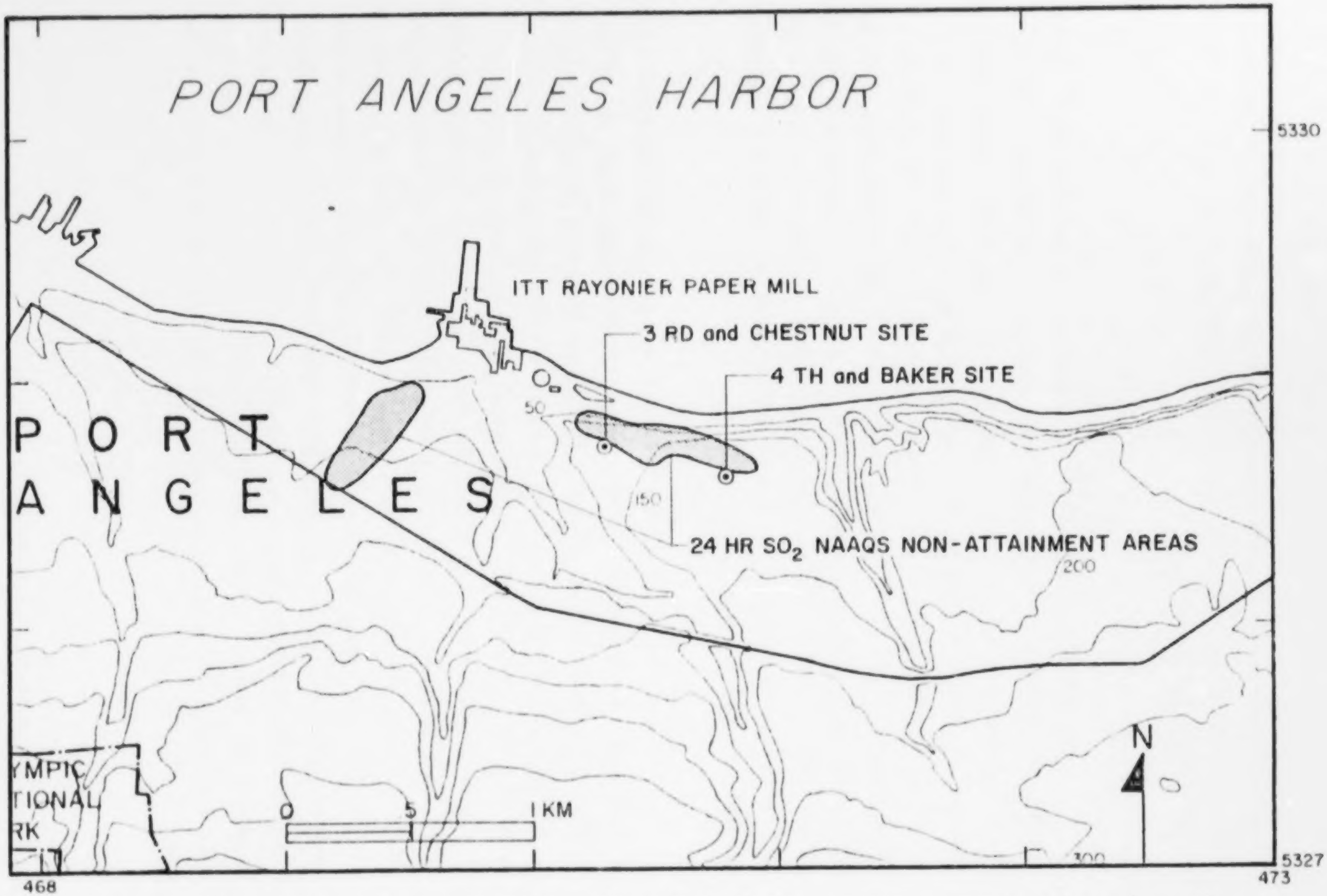

FIGURE 1 (a). Illustration of the two areas within which 24-hour average concentrations above the 24-hour National Ambient Air Quality Standard (NAAQS) for SO_2 are calculated to occur one or more times per year. The area within which 3-hour average concentrations above the 3-hour NAAQS are calculated to occur once per year is entirely contained within the area east-southeast of the ITT Mill.

in a year with a calculated concentration above the corresponding NAAQS, the only non-attainment area is the non-attainment area for the 24-hour NAAQS shown in Figure I(b).

We point out that the calculated non-attainment areas shown in Figures I(a) and I(b) consider the effects of emissions from the stacks alone. As noted above, emissions from the black liquor holding pond at the ITT Mill are believed to have a variable, but sometimes significant, impact on SO_2 air quality in the vicinity of the mill. Thus, Figures I(a) and I(b) may underestimate the actual extent of the non-attainment areas for the combined emissions from the stacks and the black liquor holding pond. (The holding pond is shown in Figure I(b) by the irregularly-shaped ellipse located north of the Third & Chestnut monitor and the non-attainment area.)

The State of Washington 1-hour SO_2 ambient air quality standard of 0.40 ppm corresponds to 1,048 micrograms per cubic meter in metric units. This standard is violated at a given point if there are two or more 1-hour concentrations in a year above 1,048 micrograms per cubic meter. Because the 1-hour concentration calculated at the point of maximum 3-hour impact for emissions from the ITT Rayonier Mill exceeds 1,048 micrograms per cubic meter during each hour of the 3-hour period, the results of the model calculations indicate that stack emissions from the ITT Mill violate the 1-hour standard. However, the maximum 1-hour concentration calculated for emissions from the Crown Zellerbach Mill alone of 592 micrograms per cubic meter is well below the 1-hour standard. It should be noted that non-compliance with the Washington 1-hour standard does not affect the attainment status of the Port Angeles area for the NAAQS.

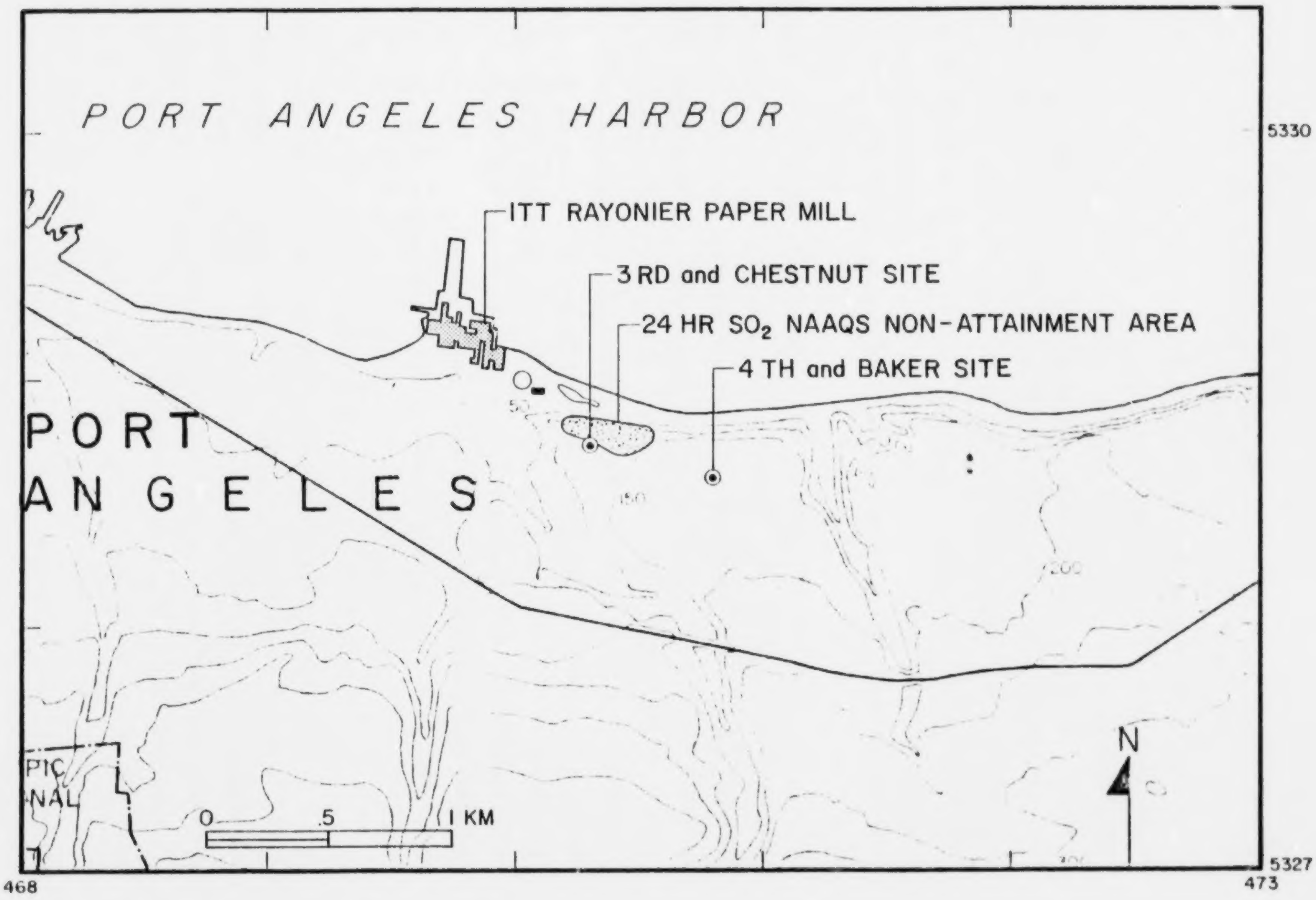

FIGURE I (b). Illustration of the area within which 24-hour average concentrations above the 24-hour National Ambient Air Quality Standard (NAAQS) for SO_2 are calculated to occur two or more times per year.

RESULTS OF THE PSD INCREMENT ANALYSIS

The "worst-case" emissions scenario for the proposed NTPC sources consists of two tankers unloading at the berths and three fully-loaded tankers idling in Port Angeles Harbor while they await berth space. The maximum short-term and annual average ground-level SO_2 concentrations calculated for the combined emissions from the five tankers at the Class I and Class II PSD areas are listed in Table V. The maximum concentrations calculated for Class I areas occur at the Olympic National Park Visitor Center and the maximum concentrations calculated for Class II areas occur in Port Angeles Harbor.

Comparison of Tables I and V shows that, for the "worst-case" emissions scenario for the proposed NTPC sources, the short-term and annual Class II PSD Increments are not exceeded in the Class II areas and the annual Class I PSD Increment is not exceeded at Olympic National Park. However, the 3-hour and 24-hour Class I PSD Increments are exceeded at Olympic National Park. Additionally, 3-hour and 24-hour concentrations above the corresponding Class I Increments are calculated to occur more than once per year at the same point at Olympic National Park. Thus, if the "worst-case" emissions scenario for the proposed NTPC sources is assumed to exist throughout the year, emissions from the NTPC sources will violate the 3-hour and 24-hour Class I Increments at Olympic National Park.

Emissions from the proposed NTPC sources will not be constant throughout the year, and the periods of "worst-case" emissions will not necessarily coincide with the periods of "worst-case" meteorological conditions. Consequently, we used the statistical procedures described in Section 4.2.3 in the main body of the report to estimate the probability that the 3-hour and 24-hour Class I PSD Increments will be violated at the Olympic National Park Visitor Center. The results of these calculations are summarized as follows:

TABLE V

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM SHORT-TERM AND ANNUAL AVERAGE SO_2 CONCENTRATIONS CALCULATED AT CLASS I AND CLASS II PSD AREAS FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

Source	Concentration (μg/m^3)		
	3-Hour	24-Hour	Annual
(a) Class I Areas (Olympic National Park)			
Tanker Unloading at West Berth	0	1.5	0.13
Tanker Unloading at East Berth	0	5.2	0.14
Tanker Idling (West Harbor)	0	0.0	0.16
Tanker Idling (Center Harbor)	71	4.6	0.17
Tanker Idling (East Harbor)	0	0.3	0.19
Total for NTPC Sources	71	11.5	0.79
(b) Class II Areas			
Tanker Unloading at West Berth	0	2	1.34
Tanker Unloading at East Berth	0	2	1.55
Tanker Idling (West Harbor)	43	7	1.26
Tanker Idling (Center Harbor)	51	15	2.22
Tanker Idling (East Harbor)	129	51	3.37
Total for NTPC Sources	222	75	9.74

- If a single occurrence of a calculated 3-hour or 24-hour average concentration above the 3-hour or 24-hour Class I Increment is interpreted as a violation of the increment, the 3-hour Class I Increment might be exceeded once every 2.0 years and the 24-hour Class I Increment might be exceeded once every 5.6 years

- If a violation of a 3-hour or 24-hour Class I Increment is defined as the occurrence at the same point of two or more calculated 3-hour or 24-hour average concentrations above the 3-hour or 24-hour Class I Increment, the 3-hour Class I Increment might be exceeded once every 6.8 years and the 24-hour Class I Increment might be exceeded once every 58.8 years

To assess the compliance of the proposed NTPC sources with the NAAQS for SO_2, we performed concentration calculations for the existing and proposed SO_2 sources using the "worst-case" emissions scenario for the NTPC sources. The results of these calculations indicate that emissions from the proposed NTPC sources do not cause the occurrence of any calculated concentration above the corresponding NAAQS that would not otherwise occur as a result of emissions from the existing sources. Also, the results of these calculations indicate that the addition of emissions from the proposed NTPC sources does not affect the dimensions of the calculated non-attainment areas shown in Figures I(a) and I(b). The contribution of emissions from the proposed NTPC sources to the maximum 3-hour average concentration calculated for the combined emissions from the existing and proposed sources is only 1 microgram per cubic meter. The contribution of emissions from the proposed NTPC sources to the maximum 24-hour average concentration calculated for the combined emissions from the existing and proposed sources is 6 micrograms per cubic meter on one of the five days with calculated 24-hour concentrations above the 24-hour NAAQS, but is less than or equal to 2 micrograms per cubic meter on each of the four remaining days. We point out that the simultaneous occurrence of the "worst-case" emissions scenario for the proposed NTPC sources and the meteorological conditions leading to the NTPC 24-hour contribution of 6 micrograms per cubic meter at the point of maximum impact for the combined emissions is likely to have a low probability.

RESULTS OF THE CONTROL STRATEGY EVALUATION

EPA Region 10 provided the eight emission control strategies for the ITT Rayonier Mill that are described in Table VI. To assist in determining how best to attain the 3-hour and/or 24-hour NAAQS in the Port Angeles area, we repeated, for each emission control strategy, the 24-hour average SO_2 concentration calculations for the five days with calculated 24-hour average concentrations above the 24-hour NAAQS and the 3-hour concentration calculations for the single 3-hour period with calculated 3-hour average concentrations above the 3-hour NAAQS. The results of these calculations, which are listed in Table VII, may be summarized as follows:

- Control Strategy 7 is the only control strategy which attains the 24-hour NAAQS if all cases of calculated 24-hour average concentrations above the 24-hour NAAQS are defined as violations of the 24-hour standard

- Control Strategies 1, 3, 5, 6, 7 and 8 attain the 24-hour NAAQS if it is assumed that a given point may have one calculated 24-hour average concentration per year above the 24-hour NAAQS without violating the 24-hour standard

- All of the control strategies preclude calculated 3-hour average concentrations above the 3-hour NAAQS

TABLE VI

DESCRIPTION OF THE EMISSION CONTROL STRATEGIES FOR THE ITT RAYONIER PULP MILL

Control Strategy Number	Control Strategy Description
1*	Duct SO_2 emissions from the West and East Vents (Acid Plant) to the Recovery Furnace Stack
2	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 250 ppm
3	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 100 ppm
4	Reduce the sulfur content of the fuel for Power Boilers No. 4 and No. 5 to 1.0%
5	Reduce the sulfur content of the fuel for Power Boilers No. 4 and No. 5 to 0.5%
6	Combine Strategies No. 2 and No. 4
7	Current Optimum ITT emissions
8	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 50 ppm

*This control strategy is contrary to Section 123 of the Clean Air Act.

TABLE VII

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE ITT RAYONIER MILL

Control Strategy Number	Occurrences of Short-Term Concentrations Above the Short-Term NAAQS		Maximum Concentration ($\mu g/m^3$)			
	SW of ITT	ESE of ITT	ITT	Crown Zellerback	Back-ground	Total
(a) 24-Hour Average Concentrations						
Existing	1	4	581	12	13	606
1	1	1	480	12	13	505
2	1	4	551	12	13	576
3	1	1	508	12	13	533
4	1	2	472	18	13	503
5	0	1	423	18	13	454
6	1	0	397	12	13	422
7	0	0	139	18	13	170
8	1	1	495	12	13	520
(b) 3-Hour Average Concentrations						
Existing	0	1	1,424	5	13	1,442
1	0	0	981	5	13	999
2	0	0	1,139	5	13	1,157
3	0	0	1,038	5	13	1,056
4	0	0	1,086	5	13	1,104
5	0	0	820	5	13	838
6	0	0	796	5	13	814
7	0	0	172	5	13	190
8	0	0	1,007	5	13	1,025

It is of interest to note that Control Strategy 7 yields the lowest calculated concentrations. Control Strategy 7 corresponds to the estimated current optimum emissions from the ITT Mill. Thus, if the ITT Mill is able to achieve and maintain the mill's current optimum emissions, the non-attainment problem will be eliminated (excluding the effects of emissions from the black liquor holding pond at the ITT Mill).

We also considered the effects of emissions from the proposed NTPC sources on the attainment status of the Port Angeles area for the eight emission control strategies for the ITT Mill. Assuming the five-tanker "worst-case" emissions scenario for the proposed NTPC sources, Table VIII summarizes the results of the 24-hour and 3-hour average SO_2 concentration calculations for the control strategies. Inspection of the table shows that, if the "worst-case" emissions from the proposed NTPC sources are assumed to apply throughout the year, emissions from the proposed NTPC source cause the 24-hour NAAQS to be exceeded more than once per year at the same point for Control Strategy 3. With this exception, the addition of emissions from the proposed NTPC sources does not affect the conclusions of the control strategy evaluation for the existing sources that are given above.

IDENTIFICATION OF THE UNCERTAINTIES IN THE MODEL CALCULATIONS

The principal areas of uncertainty affecting the accuracy of the results of the dispersion model calculations described above are the representativeness of the source input parameters, the representativeness of the meteorological input parameters and the accuracy of the Cramer, et al. (1975) complex terrain dispersion model. We assume that the source input parameters used in the model calculations, which were developed from information provided by EPA Region 10, are representative of actual operating conditions. According to Region 10 (Boys, 1980), SO_2 emissions from the ITT Mill are lower than assumed in this study during periods of optimum emissions and higher than assumed in this study during

TABLE VIII

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE ITT RAYONIER MILL WITH THE EFFECTS OF EMISSIONS FROM THE PROPOSED NTPC SOURCES INCLUDED

Control Strategy Number	Occurrences of Short-Term Concentrations Above the Short-Term NAAQS		Maximum Concentration ($\mu g/m^3$)				
	SW of ITT	ESE of ITT	ITT	Crown Zellerback	NTPC	Back-ground	Total
(a) 24-Hour Average Concentrations							
Existing	1	4	581	12	6	13	612
1	1	1	480	12	0	13	505
2	1	4	551	12	0	13	576
3	1	2	508	12	0	13	533
4	1	3	472	18	6	13	509
5	0	1	423	18	6	13	460
6	1	0	397	12	0	13	422
7	0	0	139	18	6	13	176
8	1	1	495	12	0	13	520
(b) 3-Hour Average Concentrations							
Existing	0	1	1,424	5	1	13	1,443
1	0	0	981	5	1	13	1,000
2	0	0	1,139	5	1	13	1,158
3	0	0	1,038	5	1	13	1,057
4	0	0	1,086	5	1	13	1,105
5	0	0	820	5	1	13	839
6	0	0	796	5	1	13	815
7	0	0	172	5	1	13	191
8	0	0	1,007	5	1	13	1,025

periods when the SO_2 control devices are operating at a decreased level of performance or when there are process upsets. Because of the complex meteorology and topography of the Port Angeles area, the meteorological input parameters used in the model calculations may not always be representative of meteorological conditions over the entire Port Angeles area. However, we believe that the meteorological inputs generally are representative of meteorological conditions in the areas of maximum impacts for emissions from the existing and proposed sources. In previous applications of the Cramer, et al. (1975) complex terrain dispersion model, the model has, on the average, matched the observed SO_2 concentrations to within about 20 percent. The results of the tests of the model in the Port Angeles area described above indicate that the same accuracy can be expected in the areas of maximum impacts for the existing and proposed sources.

We conclude that the maximum concentrations calculated for the existing and proposed sources probably are accurate to within about 20 percent for the source input parameters assumed in the model calculations. The uncertainties in the concentrations calculated beyond the areas of maximum impacts for emissions from the existing and proposed sources increase with distance from the sources because of the spatial variability of meteorological conditions in the Port Angeles area. Thus, the concentrations calculated at the Olympic National Park Visitor Center are subject to greater uncertainty than the concentrations calculated in the vicinity of the existing and proposed sources. We estimate that the concentrations calculated at the Visitor Center are accurate to within about a factor of two.

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SECTION 1

INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Air quality measurements in Port Angeles, Washington indicate that the 24-hour National Ambient Air Quality Standard (NAAQS) for sulfur dioxide (SO_2) was exceeded several times during 1979 near the ITT Rayonier Pulp Mill. However, the manner in which the flue gas was emitted from the ITT Mill was modified in December 1979. Consequently, the U. S. Environmental Protection Agency (EPA), Region 10 requires an ambient air quality modeling analysis to determine if the mill can be expected to continue to cause violations of the NAAQS and, if so, to determine the extent of the non-attainment area.

The Northern Tier Pipeline Company (NTPC) is proposing to build and operate a marine oil transhipment facility at Port Angeles. NTPC must obtain from EPA a preconstruction permit for Prevention of Significant Deterioration (PSD). To obtain the permit, NTPC must perform an air quality impact analysis demonstrating that the proposed NTPC sources will not cause or contribute to a violation of a NAAQS or a PSD Increment. NTPC submitted to EPA Region 10 the requisite analysis along with an application for a PSD permit on 30 June 1980. Additionally, in response to EPA comments on the 30 June 1980 analysis, NTPC submitted a revised analysis on 26 September 1980. However, because of the complexity of the topography and meteorology of the Port Angeles region, the potential for a non-attainment area and the presence of a nearby Class I PSD area (Olympic National Park), EPA Region 10 requires an independent air quality impact analysis to obtain the additional information necessary to make a decision on the approvability of the proposed NTPC project.

To satisfy the requirements for independent and objective assessments of the compliance of the existing sources in the Port Angeles area with the NAAQS for SO_2 and of the proposed NTPC project with the PSD Regulations, EPA contracted with the H. E. Cramer Company, Inc. of Salt Lake City, Utah to perform a detailed dispersion modeling analysis of the air quality impacts of emissions from the existing and proposed SO_2 sources. The results of the H. E. Cramer Company's study are summarized in this report. The specific study objectives were:

- To determine, for the existing sources, the attainment status of the Port Angeles area for the SO_2 NAAQS and, if the area is found to be a non-attainment area, to determine the extent of the non-attainment area
- To evaluate the effects of various emission control strategies identified by EPA if the existing sources are found to cause a non-attainment area for the NAAQS
- To determine the PSD Increment consumption of the proposed NTPC sources in the Class I and Class II PSD areas
- To determine if the NTPC sources will cause any area that currently is an attainment area for the NAAQS to become a non-attainment area

Table 1-1 lists the NAAQS and the Class I and Class II PSD Increments for SO_2. The State of Washington also has a 1-hour ambient air quality standard for SO_2 of 0.40 parts per million (ppm), not to be exceeded at any point more than once per year. The Washington 1-hour standard is considered in this report, although non-compliance with the 1-hour standard does not affect the attainment status of the Port Angeles area for the NAAQS.

TABLE 1-1

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) AND CLASS I AND CLASS II PREVENTION OF SIGNIFICANT DETERIORATION (PSD) INCREMENTS FOR SULFUR DIOXIDE (SO_2)

Averaging Time	NAAQS (µg/m^3)		PSD Increments (µg/m^3)	
	Primary	Secondary	Class I	Class II
3 Hours*	-	1,300	25	512
24 Hours*	365	-	5	91
Annual	80	-	2	20

*The 3-hour and 24-hour NAAQS and PSD Increments may be exceeded at any given point once per year.

1.2 DESCRIPTION OF THE SITE

Figure 1-1 is a topographic map of the Port Angeles, Washington area. Elevations in the figure are in feet above mean sea level (MSL) and the contour interval is 50 feet (15 meters). Ediz Hook, a spit protruding into the Strait of Juan de Fuca, forms Port Angeles Harbor. The existing major SO_2 sources, the Crown Zellerbach and ITT Rayonier Pulp Mills, are both located along the shoreline. As shown by Figure 1-1, the Crown Zellerbach Mill is at the base of Ediz Hook and the ITT Rayonier Mill is due south of the tip of Ediz Hook. The proposed NTPC terminal site is on Ediz Hook at a point where the width of the spit is less than 100 meters. In the "worst-case" emissions scenario for the proposed NTPC sources, two tankers are assumed to be unloading and three tankers are assumed to be idling in Port Angeles Harbor. The locations of the two unloading berths and the assumed locations of the three idling tankers are shown in Figure 1-1. It is the air quality impact of SO_2 emissions from the tankers that is of concern in this study in assessing the compliance of the proposed NTPC project with the PSD Regulations.

In general, the terrain in the Port Angeles area rises abruptly near the shoreline from sea level to about 50 meters MSL. The Olympic Mountains, which are south of the City of Port Angeles, rise to more than 800 meters MSL within 8 kilometers of the harbor and to more than 1,500 meters MSL within 13 kilometers. These mountains effectively form a barrier to storm systems from the south and significantly affect the mesoscale winds in the Port Angeles area.

Figure 1-1 also shows the locations of the meteorological and SO_2 air quality monitoring sites considered in the analyses described in this report. The ▲ symbols identify sites for which meteorological data are available, ■ symbols identify sites for which SO_2 air quality data are available and the ◆ symbols identify sites for which both meteorological and air quality data are available. These sites include:

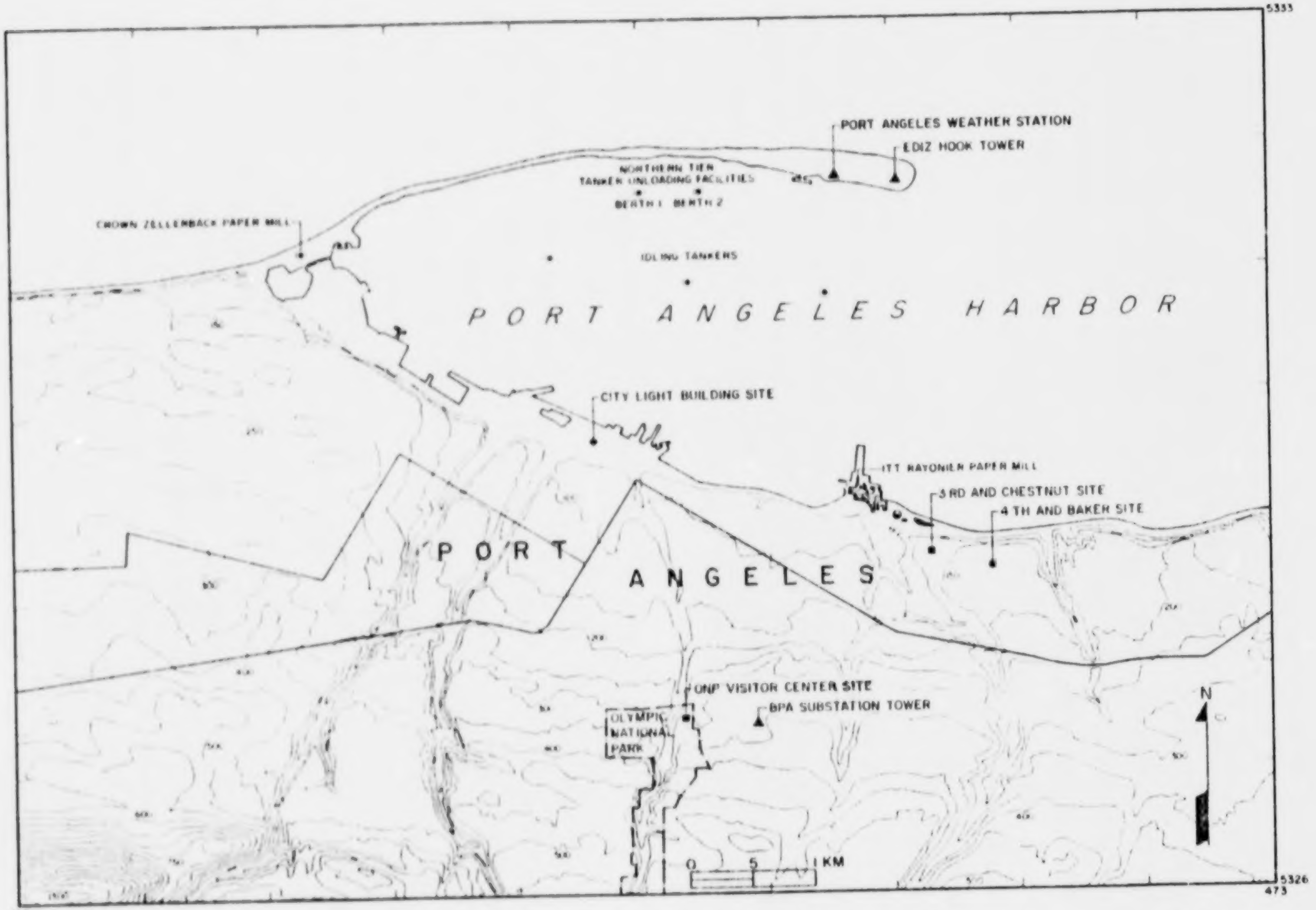

FIGURE 1-1. Topographic map of the Port Angeles area. Elevations are in feet above mean sea level (MSL) and the contour interval is 50 feet (15 meters).

- The Port Angeles weather station, which was operated by the U. S. Weather Bureau at the Coast Guard Station on Ediz Hook during the period January 1948 through December 1952

- The Ediz Hook 10-meter meteorological tower, which was operated by NTPC during the period August 1978 through August 1979

- The BPA Substation 29-meter meteorological tower, which was operated by NTPC during the period August 1978 through August 1979

- The Olympic National Park Visitor Center SO_2 monitor, which was operated by NTPC during the period August 1978 through August 1979

- The Third & Chestnut SO_2 monitor, which was operated by the Olympic Air Pollution Control Authority during during the period January through August 1979 and is still in operation

- The Fourth & Baker SO_2 monitor and 10-meter meteorological tower, which were operated by NTPC during the period April through August 1979

- The City Light Building SO_2 monitor and meteorological mast, which were operated by the Washington Department of Ecology (DOE) during the period August 1978 through August 1979 and are still in operation (the SO_2 monitor and meteorological mast were moved to West First Street during October 1979)

Table 1-2 gives the Universal Transverse Mercator (UTM) X (east-west) and Y (north-south) coordinates and elevations of the various monitoring sites. For convenience, the UTM X and Y coordinates in kilometers are indicated on the sides of Figure 1-1.

With the exception of Olympic National Park, the entire region covered by Figure 1-1 is currently designated as a Class II (moderate growth) PSD area. Olympic National Park is a mandatory Class I (pristine air quality) PSD area. As shown by Figure 1-1, the Olympic National Park Headquarters and Visitor Center are located immediately to the south of the City of Port Angeles. The distance between the proposed NTPC tanker berths and the Visitor Center is about 4 kilometers. A narrow corridor connects the Headquarters and Visitor Center section of Olympic National Park to the main part of the park, which is about 6 kilometers farther to the south.

1.3 REPORT ORGANIZATION

In addition to the Introduction, this report contains five major sections and three appendices. Section 2 discusses the source and meteorological data used in the model calculations, Section 3 describes comparisons of concurrent calculated and observed SO_2 concentrations in the Port Angeles area, Section 4 gives the calculation procedures and results for the attainment status and PSD Increment analyses, Section 5 presents the results of the model calculations for the emission control strategies, and Section 6 identifies the major areas of uncertainty in the model calculations. The Cramer, et al. (1975) complex terrain dispersion model was used in the concentration calculations described in this report. This model is implemented by the SHORTZ and LONGZ computer codes, which are documented by Bjorklund and Bowers (1979). Appendix A describes in detail the equations of the Cramer, et al. (1975) model. The statistical wind summaries used in the LONGZ calculations and the hourly meteorological

TABLE 1-2

UNIVERSAL TRANSVERSE MERCATOR (UTM) COORDINATES AND ELEVATIONS ABOVE MEAN SEA LEVEL (MSL) OF THE METEOROLOGICAL AND AIR QUALITY MONITORING SITES

Site	Coordinates		Ground Elevation (m above MSL)
	UTM X (km)	UTY Y (km)	
Port Angeles Weather Station	*	*	2
Ediz Hook Tower	470.08	5,331.70	2
BPA Substation Tower	468.91	5,327.36	104
Visitor Center SO_2 Monitor			
Aug 78 - Jan 79	468.35	5,327.21	107
Jan 79 - Aug 79	468.34	5,327.41	94
Third & Chestnut SO_2 Monitor	470.30	5,328.74	40
Fourth & Baker SO_2 Monitor	470.80	5,328.61	49
City Light Building SO_2 Monitor	467.61	5,329.63	6

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*The exact location of the wind measurement site at the U. S. Coast Guard Station on Ediz Hook is not known.

inputs used in the SHORTZ calculations are listed in Appendix B. The source and meteorological inputs for the model testing described in Section 3 are given in Appendix C.

SECTION 2

SOURCE AND METEOROLOGICAL DATA

2.1 SOURCE INPUTS FOR THE ATTAINMENT STATUS AND PSD INCREMENT ANALYSES

Table 2-1 identifies the existing and proposed SO_2 sources in the Port Angeles, Washington area by the source numbers used in the dispersion model calculations described in this report. The corresponding source inputs used in the dispersion model calculations to determine the attainment status of Port Angeles for the SO_2 National Ambient Air Quality Standards (NAAQS) as well as to determine the SO_2 air quality impacts on Class I and Class II Prevention of Significant Deterioration (PSD) areas of the proposed Northern Tier Pipeline Company (NTPC) sources are listed in Table 2-2. (The source inputs for selected historical cases that were used to test the Cramer, et al. (1975) short-term dispersion model are discussed in Section 3 and Appendix C.) The source inputs in Table 2-2 were developed from information provided by EPA Region 10 (Courson, 1980 and Wilson, 1980a). Because the West and East Vents at the ITT Rayonier Mill have identical emissions characteristics and are located in close proximity, they were represented for modeling purposes as a single stack (Source 002) with an SO_2 emission rate equal to the combined rate for the two stacks. The SO_2 emission rates for the current optimum operating conditions at the ITT and Crown Zellerbach Mills are listed in Table 2-3. Although the optimum emission rates were not used in the attainment status analysis described in Section 4.1, the optimum emission rates were considered in the control strategy analysis described in Section 5.

We point out that there are unquantified fugitive SO_2 emissions from the black liquor holding pond at the ITT Rayonier Mill that were not included in the attainment status analysis. The center of the holding pond is only about 200 meters from the Third & Chestnut SO_2 monitor and

TABLE 2-1

IDENTIFICATION OF EXISTING SO_2 SOURCES IN THE PORT ANGELES AREA BY SOURCE NUMBER

Source Number	Source Name
	ITT Rayonier Pulp Mill (Existing)
001	Recovery Furnace
002	West and East Vents (Acid Plant)
004	North Bleach Vent
005	South Bleach Vent
006	Power Boiler No. 4
007	Power Boiler No. 5
008	H. F. Boiler No. 5
	Crown Zellerbach Pulp Mill (Existing)
009	H. F. Boiler No. 8
010	Package Boiler
	Northern Tier Pipeline Company (Proposed)
011	Tanker Unloading at West Berth
012	Tanker Unloading at East Berth
013	Tanker Idling (West Harbor)
014	Tanker Idling (Center Harbor)
015	Tanker Idling (East Harbor)

TABLE 2-2

PORT ANGELES SOURCE INPUTS FOR THE ATTAINMENT STATUS AND PSD INCREMENT CALCULATIONS

Source Number	SO_2 Emission Rate (g/sec)			Source Coordinates		Stack Base Elevation (m MSL)	Stack Height (m)	Stack Exit Temp (°K)	Stack Radius (m)	Volumetric Emission Rate (m^3/sec)	
	3-Hour	24-Hour	Annual	UTM X (m)	UTM Y (m)					3-Hour & 24-Hour	Annual
001	41.3	41.3	22.4	469,790	5,329,250	3	96.0	300	1.15	50.00	50.00
002	20.8*	15.8*	10.0*	469,753	5,329,185	3	33.5	289	0.30	5.90	5.90
004	0.4	0.4	0.4	469,758	5,329,184	3	35.7	303	0.75	9.90	9.90
005	1.4	1.4	1.4	469,769	5,329,183	3	35.4	296	0.61	9.20	9.20
006	29.0	29.0	13.7	469,720	5,329,194	3	35.1	480	1.22	37.80	29.30
007	36.1	29.0	6.4	469,718	5,329,183	3	35.1	480	0.84	45.80	22.20
008	2.8	2.8	2.8	469,698	5,329,165	3	45.7	336	1.22	77.40	36.20
009	35.2	35.2	3.0	465,300	5,331,150	3	36.6	333	0.90	30.35	21.95
010	7.9	7.9	7.9	465,300	5,331,150	3	30.5	480	0.75	13.70	13.70
011	11.2	11.2	11.2	468,020	5,331,610	0	46.0	422	0.50	28.00	28.00
012	11.2	11.2	11.2	468,500	5,331,610	0	46.0	422	0.50	28.00	28.00
013	7.7	7.7	7.7	467,300	5,331,100	0	35.0	422	0.50	6.00	6.00
014	7.7	7.7	7.7	468,400	5,330,900	0	35.0	422	0.50	6.00	6.00
015	7.7	7.7	7.7	469,500	5,330,800	0	35.0	422	0.50	6.00	6.00

*Emission rates are the combined emission rates for the West and East Vents (Acid Plant).

TABLE 2-3

SO_2 EMISSION RATES FOR CURRENT OPTIMUM OPERATING CONDITIONS AT THE ITT AND CROWN ZELLERBACH MILLS

Source Number	Source Name	Current Optimum SO_2 Emission Rate (g/sec)
	ITT Rayonier Pulp Mill	
001	Recovery Furnace	22.0
002	West and East Vents (Acid Plant)	5.0*
004	North Bleach Vent	0.4
005	South Bleach Vent	1.4
006	Power Boiler No. 4	0.0
007	Power Boiler No. 5	0.0
008	H.F. Boiler No. 5	0.0
	Crown Zellerbach Pulp Mill	
009	H.F. Boiler No. 8	3.0
010	Package Boiler	7.9

*The combined emission rate for the West and East Vents (Acid Plant).

about 650 meters from the Fourth & Baker monitor. The pond is believed to be a continuous and highly variable SO_2 source (Fenske, 1980), and relatively high SO_2 concentrations have been measured at the Third & Chestnut monitor with north winds when the pond is the only upwind SO_2 source. Although the range of SO_2 emissions from the pond is unknown, significant increases in emissions are believed to occur when additional black liquor is dumped into the pond. Using concurrent emissions, meteorological, and air quality data with the Cramer, et al. (1975) dispersion model, estimates of the SO_2 emissions from the pond were calculated as part of the model testing effort and are presented in Section 3.

The emissions data provided in Table 2-2 for the proposed NTPC sources assume that two tankers are unloading at the berths shown in Figure 1-1. Additionally, three fully-loaded tankers are assumed to be idling in Port Angeles Harbor while they await berth space. According to the U. S. Coast Guard, this five-tanker configuration represents the maximum number of tankers that could be located within Port Angeles Harbor without violating safety criteria. The assumed locations of the idling tankers are also shown in Figure 1-1.

2.2 METEOROLOGICAL INPUTS FOR THE ATTAINMENT STATUS AND PSD INCREMENT ANALYSES

The meteorology of the Port Angeles area reflects the complex topography of the area to the south and the effects of the Strait of Juan de Fuca to the north. Consequently, prior to performing the dispersion model calculations for the existing and proposed SO_2 sources, we conducted a meteorological site survey of the Port Angeles area, examined in detail the meteorological data available for the area and analyzed the meteorological conditions associated with relatively high observed SO_2 concentrations in the area. Section 2.2.1 describes our analyses of the meteorological data for the Port Angeles area and Section 2.2.2 discusses the meteorological conditions associated with relatively high observed SO_2 concentrations.

The meteorological inputs used in the dispersion model calculations, which were based on the results presented in Sections 2.2.1 and 2.2.2, are given in Section 2.2.3.

2.2.1 Dispersion Meteorology of the Port Angeles Area

The following hourly meteorological data are available for 12 or more months for the Port Angeles area:

- Hourly surface weather observations made by the U. S. Weather Bureau at the Coast Guard Station on Ediz Hook during the period January 1948 through December 1952
- Hourly wind, temperature and turbulence measurements made on a 10-meter tower located near the tip of Ediz Hook during the period 15 August 1978 to 15 August 1979
- Hourly wind, temperature and turbulence measurements made on a 29-meter tower located near the BPA Substation during the period 15 August 1978 to 15 August 1979

We obtained from the National Climatic Center (NCC) a magnetic tape containing the hourly surface meteorological observations made at the Ediz Hook Coast Guard Station during the 5-year period from 1948 through 1952. Although the official station history is ambiguous, we believe that the wind measurements probably were made at a height of 17 meters on top of a hangar. Hourly meteorological data for the 10-meter and 29-meter towers were provided to us on magnetic tape by NTPC's meteorological consultant, Environmental Research and Technology, Inc. (ERT). In addition to the data for the Ediz Hook and BPA Substation meteorological towers, ERT provided us with limited wind data for NTPC's Fourth & Baker air quality monitoring site and for the Washington DOE's City Light Building air quality monitoring site. Figure 1-1 shows the locations of the various monitoring sites.

We used our Meteorological and Air Quality Statistical Analysis Program (MAQSAP) to analyze the data from the Coast Guard Station, Ediz Hook 10-meter tower and BPA Substation 29-meter tower. As discussed in Section 2.2.2, the hourly SO_2 concentration data for the Olympic National Park Visitor Center monitor were included in the MAQSAP analysis of the BPA tower data and the hourly SO_2 concentration data for the Fourth & Baker monitor were included in the MAQSAP analysis of the Ediz Hook tower data. The results of the MAQSAP analyses of the meteorological data are summarized below.

Turbulent Intensities

The equation for the standard deviation of the lateral concentraton distribution σ_y in our short-term (SHORTZ) dispersion model includes the effects of entrainment on initial plume growth and relates σ_y directly to the lateral turbulent intensity or standard deviation of the wind azimuth angle σ'_A (see Equation (A-11) in Appendix A). Similarly, the equation for the standard deviation of the vertical concentration distribution σ_z in our short-term (SHORTZ) and long-term (LONGZ) dispersion models also includes the effects of entrainment on initial plume growth and relates σ_z directly to the vertical turbulent intensity or standard deviation of the wind elevation angle σ'_E (see Equation (A-13) in Appendix A). We originally planned to use the observed σ'_A values from the Ediz Hook and/or BPA Substation meteorological towers as direct model inputs and to infer the corresponding σ'_E values from the σ'_A measurements. However, the median σ'_A values given by NTPC (1980, p. 5-44) for Ediz Hook (0.20) and the BPA Substation (0.30) are larger than the median values implicit in all but the most unstable Pasquill-Gifford σ_y curve and are not consistent with measurements at other locations (for example, see Luna and Church, 1972). The field experiments conducted at Millstone Nuclear Power Station by Johnson, et al. (1975) provide an additional consistency check on the Ediz Hook σ_A' values. The Millstone Station is on the tip of a small peninsula that extends into Long Island Sound, and the upwind fetch for all of the Millstone diffusion experiments was over water. The median hourly σ_A' for the 10-meter level of the meteorological tower was about 0.07, or about a third of the median value for Ediz Hook.

For the reasons given above, we conclude that the σ_A' measurements for the Ediz Hook and BPA Substation meteorological towers are not representative of the turbulent intensities in the Port Angeles area. Consequently, we selected the Turner (1964) stability classification scheme for use in this study. This scheme utilizes wind-speed and cloud-cover observations to estimate the Pasquill stability category and hence the lateral and vertical turbulent intensities. The nearest site for which hourly cloud-cover data are available is Whidbey Island, about 60 kilometers east-northeast of Port Angeles. We obtained the hourly cloud-cover observations from the National Climatic Center (NCC) and merged the observations with the concurrent wind data from the Ediz Hook and BPA Substation towers. The 15-meter BPA tower wind speeds were used to determine the stability category at the BPA Substation because this height is close to the airport measurement height used by the Turner scheme and to the 10-meter height used in the original Pasquill (1961) approach. However, the BPA tower 29-meter level wind speeds and directions were used in the comparisons of winds at the various locations in the Port Angeles area.

Tables 2-4 and 2-5 list the parameters that define the Pasquill stability categories following the Turner (1964) definitions. The thermal stratifications represented by the Pasquill stability categories are:

- A - Very unstable
- B - Unstable

TABLE 2-4

PASQUILL STABILITY CATEGORY AS A FUNCTION OF ISOLATION AND WIND SPEED

Wind Speed (Knots)	Insolation Index						
	4	3	2	1	0	-1	-2
0,1	A	A	B	C	D	F	F
2,3	A	B	B	C	D	F	F
4,5	A	B	C	D	D	E	F
6	B	B	C	D	D	E	F
7	B	B	C	D	D	D	E
8,9	B	C	C	D	D	D	E
10	C	C	D	D	D	D	E
11	C	C	D	D	D	D	D
≥12	C	D	D	D	D	D	D

TABLE 2-5

INSOLATION CATEGORIES

Insolation	Insolation Category Number
Strong	4
Moderate	3
Slight	2
Weak	1
Overcast < 7,000 feet (day or night)	0
Cloud Cover > 4/10 (night)	-1
Cloud Cover < 4/10 (night)	-2

- C - Slightly unstable
- D - Neutral
- E - Stable
- F - Very Stable

Average Wind Directions and Speeds

Table 2-6 lists, by season and Pasquill stability category, the average wind directions and wind speeds at the Coast Guard Station (measurement height 17 meters above ground level), the Ediz Hook meteorological tower (measurement height 10 meters above ground level) and the BPA Substation meteorological tower (measurement height 29 meters above ground level). Although the Coast Guard Station wind directions were reported to the nearest standard 22.5-degree sector (north, north-northeast, etc.) and the tower wind directions were reported to the nearest 5-degree sector, the Coast Guard Station and Ediz Hook tower average wind directions are in very close agreement. The average wind directions at the BPA tower generally are consistent with the average wind directions at the two sites on Ediz Hook. However, the differences in average wind direction between the BPA tower and either of the two sites on Ediz Hook are larger than the differences between the two sites on Ediz Hook. If allowance is made for different measurement heights and different periods of record, the Coast Guard Station and Ediz Hook tower average wind speeds compare favorably. The average wind speeds at the two Ediz Hook sites tend to be higher than the average wind speeds at the BPA tower for the C, D and E categories, a result that is probably explained by the fact that the surface roughness elements at Ediz Hook are much smaller than at the inland BPA tower. During periods of fair weather and light winds (the A, B and F categories), the average wind speeds at the BPA tower are higher than the average wind speeds at the two Ediz Hook sites. As discussed below, the winds at the BPA tower during hours with the A, B and F categories appear to be primarily determined by localized circulations.

TABLE 2-6

AVERAGE WIND DIRECTIONS AND WIND SPEEDS IN METERS PER SECOND BY SEASON AND PASQUILL STABILITY CATEGORY

Pasquill Stability Cagegory	Wind Direction (deg)/Wind Speed (m/sec)				
	Winter	Spring	Summer	Fall	Annual
(a) Coast Guard Station					
A	*	096/0.8	037/1.3	076/0.1	049/1.0
B	048/0.9	048/1.9	033/2.3	073/1.5	053/1.8
C	065/1.7	025/3.1	304/4.2	057/2.1	360/2.9
D	216/4.6	275/5.6	278/6.2	263/4.5	271/5.2
E	200/3/4	224/3.7	260/4.2	213/3.6	223/3.6
F	194/1.4	204/1.4	221/1.4	197/1.2	201/1.3
All Stabilities	201/3.8	266/4.4	278/5.2	231/3.3	259/4.2
(b) Ediz Hook 10-Meter Tower					
A	*	091/2.0	096/1.9	*	094/2.0
B	095/1.2	067/2.1	005/2.1	093/1.5	058/2.0
C	066/2.6	016/2.7	298/3.9	070/2.1	359/2.9
D	234/4.0	273/4.8	278/5.9	273/3.4	271/4.6
E	172/3.0	232/3.1	257/3.4	217/2.5	219/3.0
F	196/2.1	204/1.9	216/1.8	193/1.7	199/1.9
All Stabilities	201/3.5	257/3.7	278/4.8	216/2.7	252/3.7
(c) BPA Substation 29-Meter Tower					
A	*	013/2.0	018/2.1	*	017/2.1
B	043/1.5	017/2.3	005/2.4	038/1.9	014/2.3
C	044/2.1	357/2.6	335/3.0	028/2.2	002/2.5
D	210/2/6	291/3.2	295/3.7	230/2.4	266/2.9
E	183/2.8	231/3.1	256/3.3	191/2.7	213/2.9
F	161/2.2	184/2.2	232/2.3	174/2.2	178/2.2
All Stabilities	179/2.4	290/2.8	309/3.0	173/2.2	243/2.6

*No hours with A stability.

Table 2-6 shows that the unstable A and B Pasquill stability categories usually are associated with light winds from the northeast quadrant at Ediz Hook and the BPA tower. The slightly unstable C stability category also tends to be associated with light winds from the northeast quadrant except during the summer when moderate west-northwest winds at Ediz Hook are most common for this stability category. The tendency of the unstable Pasquill stability categories to occur with winds from the northeast quadrant may be indicative of daytime upslope winds. Sea-breeze circulations are another possible explanation for this tendency. The neutral D stability category is usually associated with moderate or strong winds at Ediz Hook from the southwest through west-northwest during all seasons. Depending on the season and the wind measurement site, the stable E and F categories generally occur with light or moderate winds from the south-southeast through south-southwest. These winds are probably nighttime drainage winds, although land-breeze circulations are another possible explanation.

Annual Wind-Direction Distributions

Figure 2-1 shows the annual wind-direction distributions for the Coast Guard Station, the Ediz Hook 10-meter tower and the BPA Substation 29-meter tower. The directions in Figure 2-1 are reversed 180 degrees in order to show the annual wind-trajectory distributions. The Coast Guard Station and Ediz Hook tower annual wind-trajectory distributions in Figure 2-1 are in close agreement. However, the BPA tower annual wind-trajectory distribution shows a much higher frequency of occurrence of winds toward the north-northwest, southwest and south-southwest and a much lower frequency of occurrence of winds toward the east than the annual wind-trajectory distributions for the two sites on Ediz Hook. The winds toward the north-northwest at the BPA tower, which are almost entirely restricted to hours with the stable E and F Pasquill stability categories, probably are nighttime drainage winds. The winds toward the southwest and south-southwest, which occur primarily with the unstable

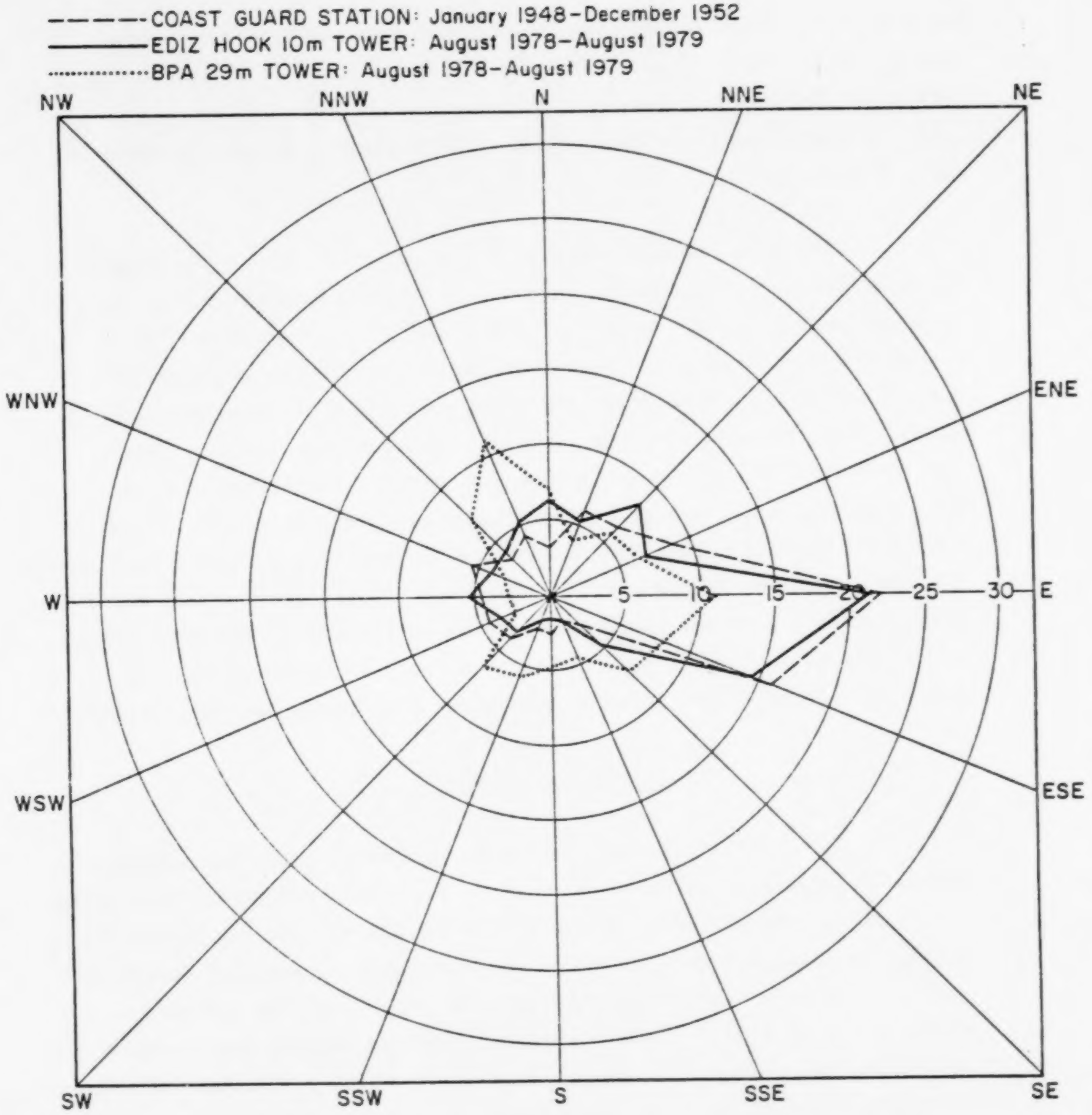

FIGURE 2-1. Annual wind direction distributions at the Coast Guard Station (dashed line), the Ediz Hook 10-meter tower (solid line) and the BPA Substation 29-meter tower (dotted line). The directions are the directions toward which the wind is blowing, and the percentage frequency scale is shown at the right center of the figure.

A, B and C stability categories, probably are daytime upslope or seabreeze winds. Thus, Figure 2-1 indicates that the winds at the inland BPA tower are more significantly affected by local influences such as nighttime drainage winds and daytime upslope winds than are the winds at Ediz Hook.

The most frequent winds near the shoreline and in the harbor, as indicated by the Coast Guard Station and Ediz Hook tower winds, are from the west and west-northwest. Table 2-7 gives the seasonal and annual occurrence frequencies of west and west-northwest winds at the two Ediz Hook sites and at the BPA tower. At all three wind measurement sites, winds from the west and west-northwest are most frequent during the summer and least frequent during the winter. Winds from the west-northwest clockwise through east-southeast are required for SO_2 emissions from the Crown Zellerbach Mill and/or the ITT Rayonier Mill to affect ambient SO_2 concentrations in the Port Angeles area. On the basis of the occurrence frequencies of west-northwest winds listed in Table 2-7, relatively high short-term SO_2 concentrations in the areas east-southeast of the two mills are far more likely during the summer than during any other season.

Wind Persistence

Table 2-8 lists, for each wind measurement site, the estimated number of cases per year with winds above 3.1 meters per second persisting within one of the sixteen standard wind-direction sectors for 12 or more hours. We point out that Table 2-8 underestimates actual wind persistence within a narrow angular sector because the table does not consider cases with mean wind directions near the boundary between two standard wind-direction sectors. However, Table 2-8 provides a relative indication of the most persistent wind directions. The results given in Table 2-8 for the Coast Guard Station and the Ediz Hook tower indicate that the most persistent wind directions along the shoreline are west and west-northwest. Persistent wind directions at the BPA Substation are rare.

TABLE 2-7

FREQUENCY OF OCCURRENCE OF WEST AND WEST-NORTHWEST WINDS

Wind Direction (Sector)	Percent Frequency of Occurrence				
	Winter	Spring	Summer	Fall	Annual
(a) Coast Guard Station					
W	10.89	22.54	38.32	16.92	22.05
WNW	5.60	16.65	30.74	10.05	15.65
W & WNW	16.49	39.19	69.06	26.97	37.70
(b) Ediz Hook 10-Meter Tower					
W	12.86	23.36	36.96	13.41	21.76
WNW	5.44	16.74	26.75	8.79	14.53
W & WNW	18.30	40.10	63.71	22.20	36.29
(c) BPA Substation 29-Meter Tower					
W	8.08	13.53	18.15	8.36	11.73
WNW	3.17	10.05	16.37	4.38	8.13
W & WNW	11.25	23.58	34.52	12.74	19.86

TABLE 2-8

ESTIMATED NUMBER OF CASES PER YEAR OF WINDS ABOVE 3.1 METERS PER SECOND PERSISTING WITHIN A STANDARD WIND-DIRECTION SECTOR FOR 12 OR MORE HOURS*

Season	Wind Direction (Sector)				
	NNE	NE	WSW	W	WNW
(a) Coast Guard Station					
Winter	0.2	0.2	0.0	0.6	0.0
Spring	0.2	0.0	0.2	3.2	1.2
Summer	0.0	0.0	0.0	4.8	7.0
Fall	0.0	0.0	0.0	1.2	0.8
Annual	0.4	0.2	0.2	9.8	9.0
(b) Ediz Hook 10-Meter Tower					
Winter	0.0	0.0	0.0	2.0	0.0
Spring	0.0	0.0	0.0	5.0	0.0
Summer	0.0	0.0	0.0	9.0	4.0
Fall	0.0	0.0	0.0	2.0	0.0
Annual	0.0	0.0	0.0	18.0	4.0
(c) BPA Substation 29-Meter Tower					
Winter	0.0	0.0	0.0	0.0	0.0
Spring	0.0	0.0	0.0	0.0	0.0
Summer	0.0	0.0	0.0	0.0	1.0
Fall	0.0	0.0	0.0	0.0	0.0
Annual	0.0	0.0	0.0	0.0	0.0

*Only the wind-direction sectors which satisfy the specified persistence criteria are listed.

Assuming that the Coast Guard Station and/or Ediz Hook tower wind directions are representative of the winds affecting the initial transport and dispersion of SO_2 emissions from the Crown Zellerbach and ITT Rayonier Mills, Table 2-8 indicates that the highest 24-hour SO_2 concentrations in the Port Angeles area attributable to these emissions generally can be expected to occur during the summer in the areas east and east-southeast of the two mills.

Wind-Speed Distributions

The seasonal and annual wind-speed distributions for the Coast Guard Station, the Ediz Hook tower and the BPA Substation tower are given in Table 2-9. For wind speeds above 3 meters per second, the wind-speed distributions at the Coast Guard Station and the Ediz Hook tower are similar. Also, the occurrence frequencies of wind speeds between 3 and 5 meters per second at the Coast Guard Station, the Ediz Hook tower and the BPA tower are all similar. However, wind speeds above 8 meters per second are far less frequent at the inland BPA tower than at the two Ediz Hook sites, and no wind speeds above 10.8 meters per second were measured at the BPA tower during the period 15 August 1978 to 15 August 1979. The differences in surface roughness between Ediz Hook and the BPA tower probably account for the absence of high wind speeds at the BPA tower.

Stability Distributions

Table 2-10 lists, for each wind measurement site, the seasonal and annual occurrence frequencies of the Pasquill stability categories. Because the same cloud cover observations were used to estimate the stability categories at the Ediz Hook and BPA Substation towers, the differences in the distributions of stability categories reflect differences in concurrent wind speeds. The 15 August 1978 to 15 August 1979 stability distribution for the Ediz Hook tower is in excellent agreement with the January 1948 through December 1952 distribution for the Coast Guard

TABLE 2-9

FREQUENCY OF OCCURRENCE OF WIND-SPEED CATEGORIES BY SEASON

Wind Speed (m/sec)	Percent Frequency of Occurrence				
	Winter	Spring	Summer	Fall	Annual
(a) Coast Guard Station					
0.0 - 1.5	27.12	23.01	16.47	38.35	26.22
1.6 - 3.0	22.92	18.70	11.58	19.31	18.19
3.1 - 5.1	30.29	27.76	27.37	24.68	27.57
5.2 - 8.2	12.79	20.27	32.49	13.51	19.69
8.3 - 10.8	3.95	6.97	9.85	2.81	5.88
>10.8	2.93	3.28	2.24	1.33	2.45
(b) Ediz Hook 10-Meter Tower					
0.0 - 1.5	11.26	10.68	8.76	22.45	13.17
1.6 - 3.0	45.63	41.29	23.56	52.58	40.66
3.1 - 5.1	26.75	23.91	27.72	14.21	23.24
5.2 - 8.2	10.34	18.16	26.75	7.38	15.78
8.3 - 10.8	4.27	5.38	11.42	2.71	5.97
>10.8	1.75	0.59	1.79	0.65	1.19
(c) BPA Substation 29-Meter Tower					
0.0 - 1.5	29.38	12.81	9.79	22.96	16.91
1.6 - 3.0	57.61	54.10	51.98	56.49	55.20
3.1 - 5.1	16.76	25.73	27.25	16.47	21.14
5.2 - 8.2	5.01	6.58	9.50	3.74	6.07
8.3 - 10.8	0.25	0.78	1.49	0.34	0.68
>10.8	0.00	0.00	0.00	0.00	0.00

TABLE 2-10

FREQUENCY OF OCCURRENCE OF PASQUILL STABILITY CATEGORIES BY SEASON

Pasquill Stability Category	Percent Frequency of Occurrence				
	Winter	Spring	Summer	Fall	Annual
(a) Coast Guard Station					
A	*	0.28	1.22	0.42	0.48
B	0.92	6.26	7.02	6.19	5.04
C	5.89	10.57	10.51	8.78	8.90
D	68.56	62.14	68.08	53.89	63.26
E	11.23	8.98	6.60	9.18	9.02
F	13.41	11.77	6.56	21.54	13.30
(b) Ediz Hook 10-Meter Tower					
A	*	0.32	1.16	*	0.37
B	0.63	9.31	8.85	3.92	5.75
C	6.21	10.90	12.05	10.40	9.90
D	60.39	52.83	61.88	50.53	56.40
E	17.82	12.55	9.68	12.66	13.16
F	14.95	14.10	6.39	22.50	14.40
(c) BPA Substation 29-Meter Tower					
A	*	0.18	2.35	*	0.59
B	1.54	12.45	17.80	4.23	8.52
C	8.78	16.04	16.54	12.34	13.19
D	47.74	39.86	36.12	41.00	41.43
E	14.33	10.59	12.14	11.80	12.29
F	27.62	20.89	15.05	30.63	23.99

*No hours with A stability.

Station. This result indicates that, on the average, the Whidbey Island cloud cover data used to determine the stability categories at the Ediz Hook tower are representative of the cloud cover at Ediz Hook. The most frequent stability category throughout the year at the two sites on Ediz Hook is the neutral D category, which occurs over 50 percent of the time during every season. The neutral D category is also the most frequent stability category at the inland BPA tower. However, unstable and stable conditions are more frequent at the BPA tower than at the two Ediz Hook sites.

Ambient Air Temperatures

Table 2-11 lists, by Pasquill stability category, the seasonal and annual average ambient air temperatures at the Coast Guard Station, the Ediz Hook tower and the BPA Substation tower. Inspection of the table shows that the average ambient air temperatures at the Coast Guard Station and the Ediz Hook tower are nearly identical. For each of the two Ediz Hook sites, the range of average ambient air temperature between seasons for a given stability category or between stability categories for a given season is less than 10 degrees Kelvin, reflecting the moderating influence of the Strait of Juan de Fuca. At the inland BPA tower, the range of average ambient air temperature between seasons for a given stability category or between stability categories for a given season is less than or equal to 15 degrees Kelvin. In general, the average ambient air temperature at the BPA tower is greater than or equal to the corresponding average ambient air temperatures at the two Ediz Hook sites for all stability categories except the very stable F category.

2.2.2 Meteorological Conditions Associated with High Observed SO_2 Concentrations in the Port Angeles Area

2.2.2.1 Maximum Average SO_2 Concentrations

Table 2-12 lists the seasonal and annual averages of the 1-hour SO_2 concentrations at the Visitor Center and Fourth & Baker monitors

TABLE 2-11

AMBIENT AIR TEMPERATURE IN DEGREES KELVIN BY PASQUILL STABILITY CATEGORY AND SEASON

Pasquill Stability Category	Ambient Air Temperature (°K)				
	Winter	Spring	Summer	Fall	Annual
(a) Coast Guard Station					
A	*	287	290	290	289
B	279	284	289	287	286
C	278	283	288	285	283
D	278	281	286	283	282
E	276	280	285	282	280
F	277	281	284	283	280
All Stabilities	278	281	286	283	282
(b) Ediz Hook 10-Meter Tower					
A	*	287	289	*	288
B	278	284	288	284	286
C	277	283	287	284	283
D	278	282	286	283	282
E	276	281	285	282	280
F	275	281	285	282	280
All Stabilities	277	282	286	283	282
(c) BPA Substation 29-Meter Tower					
A	*	290	292	*	292
B	276	286	291	285	288
C	277	284	290	285	285
D	278	283	288	283	282
E	275	281	286	282	281
F	273	279	286	281	279
All Stabilities	276	282	289	283	282

*No hours with A stability.

TABLE 2-12

AVERAGE 1-HOUR SO_2 CONCENTRATIONS AT THE VISITOR CENTER AND FOURTH & BAKER MONITORS BY PASQUILL STABILITY CATEGORY AND SEASON

Pasquill Stability Category	Average SO_2 Concentration (ppm)				
	Winter	Spring	Summer	Fall	Annual
(a) Visitor Center					
A	*	0.035	0.010	*	0.012
B	0.013	0.022	0.014	0.014	0.017
C	0.006	0.015	0.010	0.006	0.010
D	0.002	0.003	0.003	0.003	0.003
E	0.000	0.000	0.000	0.001	0.000
F	0.000	0.002	0.000	0.001	0.001
All Stabilities	0.002	0.007	0.003	0.003	0.004
(b) Fourth & Baker					
A	**	0.001	0.004	**	**
B	**	0.014	0.010	**	**
C	**	0.030	0.055	**	**
D	**	0.038	0.064	**	**
E	**	0.012	0.012	**	**
F	**	0.009	0.005	**	**
All Stabilities	**	0.027	0.050	**	**

*No hours with A stability.

**No data or insufficient data.

by Pasquill stability category. (The concentrations in this section are given in units of parts per million (ppm), the units in which the concentrations were provided on computer tape.) The BPA tower wind data were used to estimate the stability categories at the Visitor Center and the Ediz Hook tower wind data were used to estimate the stability categories at Fourth & Baker. As shown by Table 2-12, the highest average SO_2 concentrations at the Visitor Center occur during the spring and the highest average SO_2 concentrations at Fourth & Baker occur during the summer. (Although no concentration data are available for the Fourth & Baker monitor for the fall and winter months, we believe that the highest average concentrations occur at this monitor during the summer for the reasons given in Section 2.2.1.) The highest average concentrations at the Visitor Center occur with the unstable Pasquill A, B and C stability categories, a result that is consistent with daytime upslope winds or sea-breeze circulations transporting emissions from the ITT Rayonier Mill or the Crown Zellerbach Mill to the monitor. The average concentrations at the Visitor Center with the stable E and F Pasquill stability categories are near zero, reflecting the fact that these stability categories are almost always associated with offshore winds at the BPA tower. The highest average concentrations at the Fourth & Baker monitor are associated with the slightly unstable C and neutral D stability categories. With the exception of the unstable A and B stability categories, the average concentrations at Fourth & Baker are significantly higher than at the Visitor Center.

Table 2-13 gives the average of the 1-hour SO_2 concentrations at the Visitor Center monitor by wind direction and stability at the BPA Substation tower. The highest concentrations occur with the unstable A, B and C and the neutral D stability categories when the winds are from the northeast quadrant. Because northeast winds are required for the direct transport of emissions from the ITT Rayonier Mill to the monitor, the results presented in Table 2-13 suggest that the ITT Mill is the principal contributor to relatively high 1-hour SO_2 concentrations at the Visitor Center.

TABLE 2-13

AVERAGE 1-HOUR SO_2 CONCENTRATIONS AT THE VISITOR CENTER MONITOR BY WIND DIRECTION AND STABILITY AT THE BPA SUBSTATION TOWER

Direction (Sector)	Average SO_2 Concentration (ppm)						
	A	B	C	D	E	F	All Stabilities
N	0.005	0.020	0.018	0.013	0.000	0.003	0.016
NNE	0.019	0.031	0.035	0.018	0.000	0.003	0.027
NE	0.009	0.009	0.010	0.012	0.000	0.009	0.010
ENE	0.000	0.011	0.009	0.002	0.000	0.003	0.005
E	0.000	0.001	0.002	0.003	0.001	0.001	0.002
ESE	0.000	0.000	0.000	0.001	0.001	0.002	0.001
SE	0.000	0.007	0.002	0.001	0.000	0.000	0.001
SSE	0.000	0.000	0.002	0.001	0.000	0.000	0.000
S	0.000	0.000	0.002	0.001	0.000	0.001	0.001
SSW	0.000	0.000	0.000	0.001	0.000	0.000	0.000
SW	0.000	0.020	0.000	0.000	0.000	0.001	0.001
WSW	0.000	0.005	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WNW	0.000	0.000	0.000	0.001	0.000	0.002	0.001
NW	0.000	0.006	0.003	0.001	0.000	0.001	0.002
NNW	0.002	0.006	0.008	0.005	0.001	0.004	0.006
All Directions	0.012	0.017	0.010	0.003	0.000	0.001	0.004

Table 2-14 gives the average of the 1-hour SO_2 concentrations at the Fourth & Baker monitor by wind direction and stability at the Ediz Hook tower. The overall average of the 1-hour concentrations at Fourth & Baker during the monitor's approximate 4-month period of record exceeds the annual average SO_2 concentration at the Visitor Center by a factor of 10 (see Table 2-13). However, as discussed in Section 2.2.1, the highest 1-hour SO_2 concentrations at the Fourth & Baker monitor are expected during the summer (the majority of the period of record for the monitor), and the overall average concentration given in Table 2-14 probably overestimates the annual average concentration. As shown by the bottom line of Table 2-14, the highest average concentrations at Fourth & Baker are associated with the slightly unstable C and neutral D stability categories and the lowest average concentrations are associated with the very unstable A category. The critical wind directions are west-southwest through northwest and the highest average concentration for all stabilities combined occurs with west-northwest winds, the winds required for the direct transport of SO_2 emissions from the ITT Rayonier Mill to the Fourth & Baker monitor.

2.2.2.2 Maximum Short-Term SO_2 Concentrations

Definition of Critical Meteorological Regimes

The following terms are used in this section to describe meteorological regimes associated with high ground-level SO_2 concentrations: (1) the critical wind-speed condition, (2) the limited-mixing condition, (3) transition periods, and (4) sea-breeze fumigation. The critical wind-speed condition is defined as moderate or strong winds persisting within a narrow angular sector for a number of hours. In general, the critical wind-speed condition is associated with neutral or slightly unstable meteorological conditions. We define limited mixing as a period of light or moderate winds in combination with neutral or slightly stable conditions with plumes contained within a relatively shallow mixing layer. (This definition of limited mixing differs from

TABLE 2-14

AVERAGE 1-HOUR SO_2 CONCENTRATIONS AT THE FOURTH & BAKER MONITOR BY WIND DIRECTION AND STABILITY AT THE EDIZ HOOK TOWER

Direction (Sector)	Average SO_2 Concentration (ppm)						
	A	B	C	D	E	F	All Stabilities
N	0.005	0.004	0.016	0.000	0.000	0.000	0.007
NNE	0.000	0.019	0.002	0.001	0.000	0.000	0.011
NE	0.000	0.017	0.007	0.002	0.000	0.000	0.008
ENE	0.002	0.005	0.001	0.004	0.002	0.000	0.004
E	0.002	0.011	0.002	0.002	0.000	0.030	0.007
ESE	0.000	0.005	0.005	0.001	0.056	0.008	0.007
SE	0.002	0.008	0.000	0.002	0.000	0.008	0.004
SSE	0.000	0.019	0.013	0.007	0.003	0.004	0.009
S	0.000	0.007	0.000	0.013	0.005	0.007	0.007
SSW	0.000	0.010	0.000	0.002	0.000	0.003	0.002
SW	0.000	0.047	0.000	0.005	0.012	0.006	0.008
WSW	0.055	0.165	0.112	0.018	0.003	0.009	0.019
W	0.000	0.039	0.050	0.044	0.013	0.015	0.040
WNW	0.005	0.022	0.092	0.100	0.046	0.008	0.093
NW	0.002	0.006	0.023	0.039	0.002	0.000	0.021
NNW	0.002	0.002	0.000	0.004	0.000	0.000	0.002
All Directions	0.003	0.012	0.048	0.005	0.012	0.008	0.042

the TVA definition (Carpenter, et al., 1971) which is restricted to daytime hours during periods of fair weather with light-to-moderate winds below an elevated subsidence inversion.) A transition period is a relatively short period of change from a stable thermal stratification to an unstable stratification or vice versa. When the land is significantly warmer than an adjacent large body of water and a sea breeze transports the stable-to-neutral air mass that has formed above the water over land, a new unstable boundary layer begins to form at the land-water interface. A stack plume emitted near the shoreline that stabilizes above the new unstable boundary layer will travel inland with growth determined by the turbulent intensities in the marine air mass until it intersects the thermally-unstable boundary layer. The plume is then quickly mixed to the ground in a process termed sea-breeze fumigation (see Lyons and Cole, 1973).

Maximum Observed 1-Hour SO_2 Concentrations at Each SO_2 Monitor in the Port Angeles Area

To gain insight into the meteorological conditions associated with the highest observed 1-hour SO_2 concentrations in the Port Angeles area, we examined, for each SO_2 monitor, the meteorological data for the hour during each month with the highest observed 1-hour concentration. The period of record for the Olympic National Park Visitor Center (NTPC) and City Light Building (Washington DOE) monitors was 15 August 1978 to 15 August 1979. The period of record for the Third and Chestnut (Olympic Air Pollution Control Authority) monitor was 1 January to 15 August 1979 and the period of record for the Fourth & Baker (NTPC) monitor was 16 April to 15 August 1979. Wind data were available from the Ediz Hook (NTPC) and BPA Substation (NTPC) meteorological towers for the period 15 August 1978 to 15 August 1979. Additionally, wind measurements were made by NTPC at Fourth & Baker during the period of air quality monitoring at that site. We did not use the wind data from the City Light Building (Washington DOE) because it is our understanding that the wind measurements during this period were made by a mechanical weather station on a 1.5-meter

(5-foot) mast on top of the building, and we consider such data to be unreliable.

The highest 1-hour concentrations at the Visitor Center occur during the period 0800 to 1700 Pacific Standard Time (PST). The occurrence of these maximum concentrations, which typically are about 0.20 parts per million (ppm), does not show any other diurnal or seasonal trends. The only feature common to these rare cases of relatively high concentrations is the presence of light wind speeds at both the coastal and inland wind measurement sites. The wind-direction measurements for many of these cases indicate that emissions from the ITT Rayonier Mill initially traveled toward the west or southwest and then traveled upvalley to the Visitor Center. However, the ambiguity in the wind data precludes any definite statements about source-receptor relationships. On the basis of the stability categories before and during the hours with the maximum concentrations, the critical meteorological regimes for the Visitor Center are limited mixing and transition periods.

The highest 1-hour concentrations at the Third & Chestnut monitor tend to occur in the spring and summer during the period 0800 to 1700 PST. Three different meteorological regimes account for these high observed concentrations, which range from about 0.40 to 0.70 ppm. Based on the Ediz Hook wind data, the first important meteorological regime is the critical wind-speed condition with the west-northwest winds required for the direct transport of emissions from the ITT Mill to the monitor. Although the concurrent wind speeds at the inland BPA Substation tower are light, the BPA tower winds also tend to be from the west-northwest during these periods. The two other important meteorological regimes, which appear to be most frequent during the late winter and early spring, are limited mixing and transition periods. The wind speeds during these periods are light at both the Ediz Hook and BPA towers. Although the wind directions at Ediz Hook are not necessarily consistent with the directions required for the direct transport of emissions from the ITT Mill to the monitor, the BPA tower wind directions are consistent with the transport of emissions from the ITT stacks or the ITT black liquor holding pond to the monitor.

The highest 1-hour SO_2 concentrations at the Fourth & Baker monitor tend to occur during the period 0800 to 1700 PST. These concentrations range from about 0.30 to 0.50 ppm. Although insufficient data are available to determine seasonal trends, it is reasonable to assume that the seasonal trends at Fourth & Baker are the same as the seasonal trends at Third & Chestnut. Thus, the highest 1-hour SO_2 concentrations at Fourth & Baker probably occur during the spring and summer. Additionally, the critical meteorological regimes for the Fourth & Baker monitor are the critical wind-speed condition, limited mixing and transition periods.

The SO_2 concentration data available for the City Light Building indicate that the best SO_2 air quality in Port Angeles is in the vicinity of this monitor, although there are so many missing observations that no definite conclusion can be reached. The highest 1-hour SO_2 concentrations tend to occur during the period 0700 to 1700 PST. There are insufficient data to determine any seasonal trends in these relatively high concentrations, which typically are 0.05 to 0.10 ppm. The only feature common to the occurrence of relatively high concentrations at the City Light Building is the presence of light winds at all wind measurement sites. The wind directions for some of the cases are from the west or northwest, indicating that emissions from the Crown Zellerbach Mill may have affected the monitor. Similarly, the wind directions for some of the cases are from the east, indicating that emissions from the ITT Mill may have affected the monitor. However, the wind directions for several cases are from the south and appear to be the onset of a nighttime drainage flow. It is possible that SO_2 previously emitted from the ITT and/or Crown Zellerbach Mills was advected back over the monitor during these hours. The critical meteorological regimes for the City Light Building monitor are limited mixing and transition periods.

In summary, the limited-mixing condition and transition periods are associated with relatively high observed 1-hour SO_2 concentrations at all air quality monitors in the Port Angeles area. However, these conditions generally do not cause high concentrations to persist for more than a few hours. In the area east-southeast of the ITT Mill, the critical wind-speed condition with west-northwest winds is an additional important meteorological regime. High concentrations in this area associated with the critical wind-speed condition can persist for a number of hours, making the critical wind-speed condition the most important meteorological regime for a 24-hour concentration averaging time. Our examination of the concurrent meteorological and air quality data did not reveal any evidence of sea-breeze fumigations as described by Lyons and Cole (1973), a result that is consistent with our previous experience in the Puget Sound area (Cramer, *et al.*, 1976). Although we cannot exclude the possibility of sea-breeze fumigation, we have no reason to believe that it is a critical meteorological regime for the occurrence of high ground-level SO_2 concentrations for averaging times of 1-hour or longer.

Identification of the Meteorological Tower with the Most Representative Wind Directions

The only meteorological towers with sufficient hourly meteorological data for use in the dispersion model calculations are the Ediz Hook 10-meter and BPA Substation 29-meter towers. To gain insight into which of these towers provides the most representative measurements of the wind directions affecting the transport and dispersion of the emissions from the existing and proposed sources, we examined 86 hours with relatively high observed SO_2 concentrations at the Third & Chestnut and Fourth & Baker monitors. The selection criteria were:

- Observed 1-hour SO_2 concentrations greater than or equal to 0.05 ppm at both monitors

- Concurrent wind data available for the Ediz Hook 10-meter, BPA Substation 29-meter and Fourth & Baker 10-meter towers

The selected hours covered the period 24 July through 13 August 1979.

Table 2-15 lists, for each meteorological tower, the range of wind directions with observed SO_2 concentrations in our subset above 0.20 ppm at the Fourth & Baker and Third & Chestnut monitors. The ranges of wind directions for the Ediz Hook and Fourth & Baker towers are much smaller than for the BPA tower. The wind directions required for the straight-line transport of stack emissions from the nearby ITT Rayonier Mill to the Fourth & Baker and Third & Chestnut monitors are about 297 to 302 degrees and 305 to 315 degrees, respectively. Similarly, the wind directions required for the straight-line transport of emissions from the ITT black liquor holding pond to the Fourth & Baker and Third & Chestnut monitors are about 297 to 302 degrees and 306 to 006 degrees, respectively. Of the two towers for which a year of wind data are available, Table 2-15 indicates that the Ediz Hook tower has the most representative wind directions if emissions from the ITT Mill are assumed to be responsible for the relatively high SO_2 concentrations observed east-southeast of the mill. Also, as indicated by the Fourth & Baker tower wind directions, the Ediz Hook tower wind directions are more representative of wind directions along the shoreline where the existing sources are located than are the BPA tower wind directions.

2.2.3 Meteorological Inputs to the SHORTZ and LONGZ Computer Programs

The Cramer, et al. (1975) complex terrain dispersion model is implemented by the SHORTZ and LONGZ computer codes. The hourly meteorological inputs required by the SHORTZ program are listed in Table 2-16 and the seasonal meteorological inputs required by the LONGZ program are listed in Table 2-17. On the basis of our review of the meteorological and air quality data for the Port Angeles area (see Sections 2.2.1 and 2.2.2), we selected what we considered to be the most representative of the available data to develop the meteorological inputs for use in the dispersion model calculations, following the general guidance given in Section 2 of the User's Guide for the SHORTZ and LONGZ programs (Bjorklund and Bowers, 1979).

TABLE 2-15

RANGE OF WIND DIRECTIONS ASSOCIATED WITH OBSERVED 1-HOUR SO_2 CONCENTRATIONS ABOVE 0.20 PPM

Tower (Measurement Height)	Range of Wind Directions (deg)
(a) Fourth & Baker Monitor	
Ediz Hook (10 m)	270 to 300
BPA Substation (29 m)	290 to 060
Fourth & Baker (10 m)	295 to 335
(b) Third & Chestnut Monitor	
Ediz Hook (10 m)	275 to 310
BPA Substation (29 m)	300 to 040
Fourth & Baker (10 m)	300 to 335

TABLE 2-16

HOURLY METEOROLOGICAL INPUTS REQUIRED BY THE SHORTZ PROGRAM

Parameter	Definition
$\bar{u}_R$	Mean wind speed (m/sec) at height z_R
DD	Mean wind direction (deg) at height z_R
p	Wind-profile exponent
σ'_A	Wind azimuth-angle standard deviation in radians
σ'_E	Wind elevation-angle standard deviation in radians
T_a	Ambient air temperature ($^{\circ}$K)
H_m	Depth of surface mixing layer (m)
$\frac{\partial\theta}{\partial z}$	Vertical potential temperature gradient ($^{\circ}$K/m)

TABLE 2-17

TABLES OF METEOROLOGICAL INPUTS REQUIRED BY THE LONGZ PROGRAM

Parameter/Table	Definition
$f_{i,j,k,\ell}$	Frequency distribution of wind-speed and wind-direction categories by stability or time-of-day categories for the ℓ^{th} season
$\bar{u}\{z_R\}_i$	Mean wind speed (m/sec) at height z_R for the i^{th} wind-speed category
$P_{i,k}$	Wind-profile exponent for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$\sigma'_{E;i,k}$	Standard deviation of the wind-elevation angle in radians for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$T_{a;k,\ell}$	Ambient air temperature for the k^{th} stability or time-of-day category and ℓ^{th} season
$\left(\frac{\partial\theta}{\partial z}\right)_{i,k}$	Vertical potential temperature gradient for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$H_{m;i,k,\ell}$	Median surface mixing depth for the i^{th} wind-speed category, k^{th} stability or time-of-day category and ℓ^{th} season

The existing SO_2 sources in the Port Angeles area (the Crown Zellerbach and ITT Rayonier Mills) are all located along the shoreline, and the proposed NTPC SO_2 sources (tankers) will be located in Port Angeles Harbor. Our review of the hourly meteorological data available for the Port Angeles area (see Section 2.2.1) indicated that there are, at times, differences in concurrent wind speeds, wind directions and Pasquill stability categories at the various meteorological measurement sites. That is, the meteorological data from a single site cannot always be expected to be representative of meteorological conditions over the entire Port Angeles area. Because the SHORTZ and LONGZ programs are designed to use meteorological data from a single site, we selected for use in the dispersion model calculations the data from the site most likely to be representative of meteorological conditions in the areas of maximum impacts for emissions from the existing and proposed SO_2 sources. In our opinion, the wind-speed data from the 10-meter Ediz Hook tower are most likely to be representative of the winds affecting the initial dilution of emissions from the existing and proposed sources. Also, our review of the wind-direction data for the hours with high observed SO_2 concentrations at the Fourth & Baker and Third & Chestnut monitoring sites (see Section 2.2.2) indicated that the Ediz Hook tower wind directions more closely reflect the wind directions along the shoreline than do the BPA Substation tower wind directions. Finally, the good correspondence between the wind-speed, wind-direction and Pasquill stability category distributions for the Coast Guard Station during the period January 1948 through December 1952 and the Ediz Hook tower during the period 15 August 1978 to 15 August 1979 supports the validity of the Ediz Hook tower data.

The Ediz Hook hourly wind directions and wind speeds were used as direct inputs to the SHORTZ program and were also used to generate seasonal tabulations of the joint frequency of occurrence of wind-speed and wind-direction categories, classified according to the Pasquill stability categories, for input to the LONGZ program. The hourly meteorological inputs for the "worst-case" short-term periods as well as the seasonal wind summaries are contained in Appendix B.

The SHORTZ and LONGZ programs account for the variation with height of the wind speed by means of a wind-profile exponent law of the form

$$\bar{u}\{z\} = \bar{u}\{z_R\}\left(\frac{z}{z_R}\right)^p \qquad (2\text{-}1)$$

where $\bar{u}\{z\}$ is the mean wind speed at height z, $\bar{u}\{z_R\}$ is the mean wind speed at height z_R and p is the wind-profile exponent. The report on the Millstone field experiments (Johnson, et al., 1975), which are discussed in Section 2.2.1, provides hourly mean wind speeds at heights above the surface of 10, 19.5, 43.3, 114 and 136 meters for 36 hours when the upwind fetch was over water. We used Equation (2-1) in the User's Guide for the SHORTZ and LONGZ programs (Bjorklund and Bowers, 1979) with the tower wind data to calculate a wind-profile exponent for each hour. The Millstone wind-profile exponents ranged from 0.04 to 0.28. The median value was 0.07 and the mean value was 0.11, which we believe to be characteristic of a marine air mass with an over-water trajectory. The only multilevel meteorological tower in the Port Angeles area is the BPA Substation tower. The annual average wind speeds at the 29-meter and 15-meter levels of the BPA tower are 2.6 and 2.4 meters per second, respectively. These annual average wind speeds imply an annual average wind-profile exponent of 0.12, which is in close agreement with the average wind-profile exponent for the Millstone diffusion experiments. We therefore set the wind-profile exponent equal to 0.10 for every hour in the SHORTZ calculations and for every seasonal combination of wind-speed and Pasquill stability categories in the LONGZ calculations.

The Cramer, et al. (1975) dispersion model assumes that lateral and vertical plume growth are directly related to the lateral and vertical turbulent intensities. As explained in Section 2.2.1, we do not consider the lateral turbulent intensities measured on the Ediz Hook and BPA Substation towers to be representative. Consequently, we merged the Ediz Hook tower wind data with concurrent Whidbey Island cloud cover data to assign the Pasquill stability category to each hour following the Turner (1964) approach (see Tables 2-4 and 2-5). In a previous modeling study in the Puget Sound area, the vertical (σ'_E) and lateral (σ'_A) turbulent intensities suggested by Cramer, et al. (1975) for the Pasquill stability categories in rural areas yielded a close correspondence between the 1-hour SO_2 concentrations calculated by the SHORTZ program and the concurrent observed concentrations (see Table 4-6 of Cramer, et al., 1976). The test cases in the Cramer, et al. (1976) study included plume trajectories over land, over water and over both water and land that were longer than the plume trajectories of concern for this study. Because of our previous success in using the Cramer et al. (1975) rural turbulent intensities in a similar application, we selected these turbulent intensities for use in this study.

Table 2-18 lists the turbulent intensities suggested by Cramer, et al. (1975) for rural areas. (We point out that, if it were not for the moderating influence of the marine air mass, the turbulent intensites suggested by Cramer, et al. (1975) for urban areas probably would be appropriate for use in this study because of the complex terrain of the Port Angeles area.) The turbulent intensities in Table 2-18 were assigned to each hour for use in the dispersion model calculations on the basis of the Pasquill stability category as determined by the Ediz Hook tower wind speed and the concurrent Whidbey Island cloud-cover observation. Because the Ediz Hook tower wind directions were reported to the nearest 5-degree sector, an N-hour lateral turbulent intensity (obtained using the $t^{1/5}$ law of Osipov, 1972 and others) was assigned to each hour of an N-hour period with the same wind direction and stability in the 3-hour and 24-hour SO_2 concentration calculations. For example, if D stability and the same wind direction were reported for 3 consecutive hours, the 1-hour σ'_A value

TABLE 2-18

HOURLY VERTICAL AND LATERAL TURBULENT INTENSITIES USED IN THE CONCENTRATION CALCULATIONS

Pasquill Stability Category	Turbulent Intensities (rad)	
	Vertical (σ'_E)	Lateral (σ'_A)
A	0.1745	0.2495
B	0.1080	0.1544
C	0.0735	0.1051
D	0.0465	0.0665
E	0.0350	0.0501
F	0.0235	0.0336

for D stability was multiplied by 1.25 ($3^{1/5}$) and assumed to apply during each hour of the 3-hour period. The purpose of this adjustment was to account in part for the effects of the actual variability of the wind direction within the 5-degree sector. The EPA Single Source (CRSTER) Model modifies the reported wind directions by means of a random number generator in a similar attempt to account for these effects.

The Cramer, et al. (1975) dispersion model defines the top of the surface mixing layer as the height at which the vertical intensity of turbulence becomes effectively zero. This condition is fulfilled when the vertical intensity of turbulence is on the order of 0.01 or less. Because measurements of the vertical profile of the intensity of turbulence are not routinely made, indirect indicators such as discontinuities in the vertical wind and temperature profiles generally are used to estimate the depth of the surface mixing layer. In the simplest case, the base of an elevated inversion layer is usually assumed to represent the top of the surface mixing layer. However, even with a surface-based inversion or isothermal layer, the Cramer, et al. (1975) model assumes that a mechanical mixing layer will exist due to the presence of surface roughness elements. That is, the depth of the surface mixing layer is determined by both convective and mechanical processes.

NTPC (1980) used Quillayute rawinsonde data with the mixing depth estimation scheme of Benkley and Schulman (1979) to calculate hourly mixing depths for the period 15 August 1978 to 15 August 1979. (The Quillayute rawinsonde observations were adjusted to account for the difference in elevation between Quillayute and Port Angeles.) The Benkley and Schulman scheme is consistent with the concepts of the mixing depth implicit in the Cramer, et al. (1975) model in that it considers the effects of both mechanical and convective turbulence in estimating the mixing depth. During the nighttime hours or during the daytime hours when the effects of convection are weak, the mixing depth in meters is given by

$$H_m \approx 90\ \bar{u} \tag{2-2}$$

where $\bar{u}$ is the 3-hour average wind speed in meters per second for the 3-hour period centered on the hour for which the mixing depth is calculated. After adjustment for temperature advection, the uniform potential temperature method (see Holzworth, 1972) is used to define the convective mixing depth during the daytime hours. If the mechanical mixing depth exceeds the corresponding convective mixing depth, the mechanical mixing depth is assumed to apply.

Quillayute is about 80 kilometers west-southwest of Port Angeles on the Pacific Coast and, in the absence of mixing depth measurements for Port Angeles, we have no basis for assessing the representativeness of the hourly mixing depths given for Port Angeles by NTPC (1980). However, we used the hourly mixing depths provided by NTPC (1980) in the SHORTZ calculations because: (1) The mechanical component of the Benkley and Schulman (1980) scheme appears to dominate the calculated mixing depths, (2) We believe Equation (2-2) to be a reasonable first approximation to the mechanically-induced mixing depth, and (3) No other mixing depth data were available. For the LONGZ calculations, we used the Ediz Hook tower wind data with the NTPC (1980) hourly mixing depth estimates to determine the seasonal median mixing depths for the various combinations of wind-speed and Pasquill stability categories. The resulting median mixing depths are listed in Table 2-19.

The plume rise equations used by the SHORTZ and LONGZ programs (see Section A.2 of Appendix A) require the ambient air temperature and vertical potential temperature gradient as inputs. The Ediz Hook tower ambient air temperature measurements were used as direct inputs to the SHORTZ program and the seasonal average temperatures given in Table 2-11 for the Coast Guard Station were used as inputs to the LONGZ program. (The Coast Guard Station average temperatures were used in preference to the Ediz Hook tower average temperatures in the LONGZ calculations because they cover a 5-year rather than a 1-year period.) Table 2-20 gives, by season and Pasquill stability category, the average relative humidities at

TABLE 2-19

MEDIAN MIXING DEPTHS IN METERS USED IN THE LONGZ CALCULATIONS*

Pasquill Stability Category	Ediz Hook 10m Wind Speed (m/sec)					
	0.0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8
(a) Winter						
A	(225)	(225)	-	-	-	-
B	225	(225)	(225)	-	-	-
C	125	200	275	(275)	(275)	(275)
D	125	125	175	350	550	600
E	-	125	225	-	-	-
F	175	175	-	-	-	-
(b) Spring						
A	450	600	-	-	-	-
B	550	650	1500	-	-	-
C	250	600	850	1500	(1500)	(1500)
D	175	225	350	350	550	2000
E	-	175	225	-	-	-
F	175	175	-	-	-	-
(c) Summer						
A	500	950	-	-	-	-
B	550	850	1500	-	-	-
C	350	650	850	750	850	1500
D	175	225	225	350	550	500
E	-	175	225	-	-	-
F	125	175	-	-	-	-
(d) Fall						
A	(175)	(400)	-	-	-	-
B	175	400	1500	-	-	-
C	275	225	350	350	(350)	(350)
D	125	175	225	350	650	550
E	-	125	175	-	-	-
F	125	175	-	-	-	-

*Median mixing depths enclosed by parentheses are estimates for the joint combinations of wind-speed and stability categories which did not occur in the observations.

TABLE 2-20

AVERAGE RELATIVE HUMIDITIES IN PERCENT AT THE COAST GUARD STATION

Pasquill Stability Category	Relative Humidity (%)				
	Winter	Spring	Summer	Fall	Annual
A	*	67	71	71	71
B	66	68	73	72	71
C	74	72	76	78	75
D	82	79	84	85	83
E	81	81	86	85	83
F	85	83	89	87	86
All Stabilities	82	78	83	84	82

*No hours with A stability.

the Coast Guard Station. The average humidity is high for all combinations of season and Pasquill stability categories, reflecting the marine air mass over the harbor and along the shoreline. Because plume rise for the existing and proposed SO_2 sources will be determined by the vertical potential temperature gradient of the marine air mass, we set the vertical potential temperature gradient equal to the moist adiabatic value of 0.003 degrees Kelvin per meter for each hour in the SHORTZ calculations and for each seasonal combination of wind-speed and stability categories in the LONGZ calculations. (The mean vertical potential temperature gradient for the Millstone field experiments was 0.002 degrees Kelvin per meter.)

As noted in Section 4.2, it was necessary to calculate, for every hour of the year, the 1-hour average SO_2 concentration at the Olympic National Park Visitor Center attributable to emissions from the proposed NTPC sources. In general, the meteorological inputs for the "brute force" concentration calculations were developed following the procedures outlined above. However, because the results of the hourly concentration calculations were used to form both 3-hour and 24-hour average concentration frequency distributions, we used a random number generator rather than N-hour lateral turbulent intensities to account for the variability of wind directions reported to the nearest 5-degree sector.* That is, a random number in 0.5-degree increments between -2.5 and +2.5 degrees was added to each wind-direction observation. Also, wind speeds less than 1 meter per second were set equal to 1 meter per second for consistency with standardized EPA dispersion modeling techniques. No concentration calculations were performed for hours with calm or light and variable winds (about 0.2 percent of the total number of hours in the year) because there is no objective basis for specifying plume trajectories or lateral plume dimensions under these conditions. If the Ediz Hook tower wind-direction or wind-speed observation was missing for an hour, we substituted the concurrent wind-direction or wind-speed observation from the 29-meter level of the BPA Substation tower. In the absence of a temperature measurement for the Ediz Hook tower, a temperature was assigned to the hour on the basis of season and the Pasquill stability category using the values given in Table 2-10(a). Similarly, in the absence of a mixing depth estimate, a mixing depth was assigned to the hour on the basis of season, wind speed and Pasquill stability category using the values in Table 2-19.

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*The use of N-hour lateral turbulent intensities in the "brute force" concentration calculations would have required the manual preparation of two different sets of hourly meteorological inputs, one for the 3-hour concentration calculations and one for the 24-hour concentration calculations.

SECTION 3
SUMMARY OF THE RESULTS OF MODEL TESTING

The Port Angeles area presents a very difficult dispersion modeling problem because of the complexity of the topography and meteorology. The Cramer, et al. (1975) complex terrain dispersion model was selected for use in this study because it has worked well in a previous study in the Puget Sound area (Cramer, et al., 1976) as well as in other studies of the air quality impact of SO_2 emissions from sources in complex terrain (for example, Cramer and Bowers, 1976 and U. S. versus West Penn Power, 1978). However, it is important to assess the accuracy of the model in the Port Angeles area by means of direct comparisons of concurrent calculated and observed SO_2 concentrations. Also, the results of the model testing provide insight into the representativeness of the meteorological data to be used in the attainment status and PSD analyses for the existing and proposed SO_2 sources, all of which are located along the shoreline or in the harbor.

The Third & Chestnut and Fourth & Baker SO_2 monitors have measured the highest SO_2 concentrations in the Port Angeles area. Both of these monitors are located near the largest existing SO_2 source in the area, the ITT Rayonier Pulp Mill. Consequently, we used the air quality measurements from these monitors for model testing. Because of the time and level-of-effort constraints for the performance of this study, we restricted our model testing to a detailed examination of 20 hours with relatively high observed concentrations at both monitors. The selection criteria were as follows:

- An observed 1-hour SO_2 concentration at one of the two monitors greater than or equal to 0.20 parts per million (ppm) and a concurrent observed concentration at the second monitor greater than or equal to 0.05 ppm

- Availability of complete meteorological data for both the Ediz Hook and BPA Substation meteorological towers

- Operation of a minimum of three of the six ITT SO_2 sources for which emissions data were available

We added the third selection criterion because all of the ITT SO_2 sources were to be considered in the attainment status analysis, and we wished to test the performance of our model under conditions approximating the operating conditions for the attainment status calculations.

Table 3-1 identifies the 20 hours selected for model testing and gives the Pasquill stability categories and mean wind directions and speeds at the Ediz Hook and BPA Substation meteorological towers. As shown by the table, the mean wind speeds at the 29-meter level of the BPA tower are significantly lower than the concurrent wind speeds at the 10-meter Ediz Hook tower. The differences in wind speeds between the two towers lead to the differences in stability categories as estimated following the Turner (1964) definitions of the Pasquill stability categories. As explained in Section 2.2.3, we believe that the Ediz Hook wind data are most likely to be representative of the winds affecting the initial dilution and transport of emissions from both the existing and proposed SO_2 sources. The Ediz Hook tower data were used to develop the hourly meteorological inputs for the model testing following the procedures outlined in Section 2.2.3.

Table 3-2 gives, for each hour selected for model testing, the observed SO_2 concentrations at the Fourth & Baker, Third & Chestnut and Visitor Center air quality monitors. The wind directions required to transport emissions from the Crown Zellerbach and ITT Mills to the area containing the Fourth & Baker and Third & Chestnut monitors do not correspond to the directions required to transport emissions from the two mills to the Visitor Center monitor. Because of the occurrence of relatively

TABLE 3-1

IDENTIFICATION OF THE CASES SELECTED FOR MODEL TESTING

Case No.	Date	Hour (PST)	Pasquill Stability Category		Wind Direction/Speed (m/sec)	
			Ediz Hook	BPA Substation	Ediz Hook 10 m	BPA 29 m
1	1 Jun 79	1800	D	B	290/6.7	330/1.3
2	2 Jun 79	0900	D	B	290/6.0	010/1.1
3		1400	D	B	300/6.5	020/2.0
4		1500	D	B	290/8.5	315/2.2
5		1600	D	C	285/10.5	275/4.9
6	9 Jun 79	1500	D	B	285/10.1	330/3.6
7		1600	D	C	280/9.8	310/4.0
8		1700	D	C	280/10.3	300/4.5
9	12 Jun 79	1800	D	D	280/7.2	310/5.8
10	24 Jul 79	1600	D	C	305/6.5	359/2.2
11		2000	D	F	295/8.7	060/1.3
12	26 Jul 79	1100	D	D	300/6.3	350/1.8
13	30 Jul 79	1900	D	D	290/8.0	310/2.7
14	31 Jul 79	0900	C	B	310/4.0	335/2.7
15		1000	D	B	295/6.0	340/2.7
16		1100	D	C	300/7.2	325/4.0
17		1200	D	C	290/7.2	330/4.7
18		1300	D	C	285/7.4	320/4.7
19		1400	D	C	290/8.3	300/4.7
20		1500	D	D	290/11.0	300/5.8

TABLE 3-2

OBSERVED SO_2 CONCENTRATIONS AT THE FOURTH & BAKER, THIRD & CHESTNUT AND VISITOR CENTER MONITORS DURING THE HOURS SELECTED FOR MODEL TESTING

Case No.	Concentration (ppm)		
	Fourth & Baker	Third & Chestnut	Visitor Center
1	0.25	0.11	0.00
2	0.21	0.27	0.00
3	0.18	0.23	0.01
4	0.29	0.13	0.00
5	0.28	0.13	0.00
6	0.23	0.09	0.00
7	0.30	0.08	0.00
8	0.31	0.07	0.00
9	0.22	0.13	0.00
10	0.16	0.33	0.00
11	0.22	0.19	0.00
12	0.07	0.20	0.00
13	0.46	0.19	0.00
14	0.09	0.30	0.03
15	0.14	0.47	0.00
16	0.31	0.17	0.00
17	0.24	0.12	0.00
18	0.24	0.06	0.00
19	0.20	0.15	0.00
20	0.23	0.13	0.00

high SO_2 concentrations at the Fourth & Baker and Third & Chestnut monitors during the hours selected for model testing, it is reasonable to assume that the monitors were being affected by emissions from the ITT Mill and/or the Crown Zellerbach Mill. Additionally, the Ediz Hook wind directions during these hours indicate that emissions from the ITT Mill and/or the Crown Zellerbach Mill were transported toward the Fourth & Baker and Third & Chestnut monitors. For the hours with moderate wind speeds at the BPA Substation tower, the BPA tower wind directions also indicate that emissions from the ITT Mill and/or the Crown Zellerbach Mill were transported to the monitors. Consequently, we assumed that the SO_2 concentrations at the Visitor Center during these hours were representative of the "background", which we define for the purpose of model testing as ambient SO_2 concentrations attributable to sources other than the ITT and Crown Zellerbach Mills. As shown by Table 3-2, the background for the hours selected for model testing ranges from 0.00 to 0.03 ppm. The background concentrations at the Visitor Center were added to the calculated concentrations for comparison with the observed concentrations at the Fourth & Baker and Third & Chestnut monitors.

After the selection of the 20 hours for model testing, we learned that the black liquor holding pond at the ITT Mill is a continuous and highly variable source of SO_2 emissions and may have a significant impact on ambient air quality (Fenske, 1980). Our inspection of the Ediz Hook wind directions during the hours selected for model testing indicated that the concentrations measured at Third & Chestnut during these hours probably were almost entirely determined by emissions from the ITT stacks, while the concurrent concentrations at Fourth & Baker were determined by the combined emissions from the ITT stacks and the holding pond. Because the emissions from the holding pond are unquantified, we used the calculated centerline concentrations at the Third & Chestnut monitor to test the performance of our model for the stack emissions. (That is, we assumed that the wind transported the merged ITT plume in a straight line to the Third & Chestnut monitor during each of the 20 hours.) Assuming a "perfect model" and representative model inputs as well as air quality observations, the calculated centerline concentrations at Third & Chestnut should be greater than or equal to the corresponding observed concentrations for every hour. Also, the mean ratio (MR) of calculated to observed concentrations for a large sample should be about 1.75 for the reasons given below. The MR for calculated centerline to observed concentrations is defined as

$$MR = \left[\frac{\sum_{i=1}^{N} \chi_{cc_i}}{N}\right]\left[\frac{\sum_{i=1}^{N} \chi_{oi}}{N}\right]^{-1}$$

$$= \left[\bar{\chi}_{cc}\right]\left[\bar{\chi}_{o}\right]^{-1} \qquad (3\text{-}1)$$

where χ_{cc_i} is the i^{th} calculated centerline concentration and χ_{oi} is the i^{th} observed concentration.

The angular width of the wind-direction sector required to transport stack emissions from the ITT Mill to the Third & Chestnut monitor is approximately given by the angular width of the merged ITT plume at the monitor. If it is assumed that all wind directions within this sector are equally probable, the sum of a large sample of the hourly SO_2 concentrations produced at the monitor, divided by the number of observations, yields a sector-averaged concentration. The width of this sector is 4.3 σ_y, where σ_y is the lateral dispersion coefficient. For a Gaussian distribution, the ratio of the average concentration within the sector 2.15 σ_y to the centerline concentration is 0.57 (Cramer, et al., 1972). Thus $\bar{\chi}_o$ in Equation (3-1) is approximately given by

$$\bar{\chi}_o = 0.57\ \bar{\chi}_{oc} \qquad (3\text{-}2)$$

where $\bar{\chi}_{oc}$ is the average of the actual centerline concentrations at the distance of the monitor. Consequently, Equations (3-1) and (3-2) give the expected value of the MR as

$$MR = \left[\bar{\chi}_{cc}\right]\left[0.57\ \bar{\chi}_{oc}^{\ -1}\right] = 1.75\ \bar{\chi}_{cc}/\bar{\chi}_{oc} \tag{3-3}$$

In the absence of any systematic errors in the model, the model inputs or the air quality measurements, the ratio $\bar{\chi}_{cc}/\bar{\chi}_{oc}$ should be unity, leading to an expected MR of 1.75.

We used the source and meteorological inputs given in Appendix C with the short-term dispersion model (SHORTZ) described in Section A.3 of Appendix A, including the terrain adjustment procedures outlined in Section A.5, to calculate the 1-hour centerline SO_2 concentration at the Third & Chestnut monitor for each hour selected for model testing. Table 3-3 compares the calculated centerline and corresponding observed 1-hour SO_2 concentrations at the Third & Chestnut monitor for the 20 hours. With the exception of Cases 10, 11 and 15, all of the calculated centerline concentrations are greater than or equal to the corresponding observed concentrations. According to the Washington DOE (Fensky, 1980), the pollution control system used by the ITT Mill during the period containing the hours selected for model testing was unreliable, and SO_2 emissions from several of the low-level sources at the mill could have been higher than estimated by ITT without ITT's knowledge. Thus, the failure of the calculated centerline concentrations to equal or exceed the observed concentrations during Cases 10, 11 and 15 is possibly explained by the fact that the emission rates used in the model calculations are lower than the actual emission rates during these hours. The MR of 1.85 is in close agreement with the expected value of 1.75 and indicates that, on the average, the model is accurate to within about 10 percent. This result is consistent with our previous experience

TABLE 3-3

COMPARISON OF CALCULATED CENTERLINE AND CORRESPONDING OBSERVED 1-HOUR SO_2 CONCENTRATION AT THIRD & CHESTNUT

Case	Concentration (ppm)		Ratio of Calculated and Observed Concentrations
	Observed	Calculated Centerline*	
1	0.11	0.32	2.91
2	0.27	0.32	1.19
3	0.23	0.30	1.30
4	0.13	0.22	1.69
5	0.13	0.18	1.38
6	0.09	0.35	3.89
7	0.08	0.37	4.63
8	0.07	0.37	5.29
9	0.13	0.56	4.31
10	0.33	0.23	0.70
11	0.19	0.17	0.89
12	0.20	0.36	1.80
13	0.19	0.43	2.26
14	0.30	0.30	1.00
15	0.47	0.44	0.94
16	0.17	0.37	2.18
17	0.12	0.37	3.08
18	0.06	0.36	6.00
19	0.15	0.32	2.13
20	0.13	0.24	1.85
		Mean Ratio (MR)	1.85

*The calculated concentrations include background (the concurrent SO_2 concentrations measured at the Visitor Center).

in testing the model in similar applications (see Section 6). We point out that the contribution of emissions from the Crown Zellerbach Mill to the calculated concentrations in Table 3-3 is less than 0.01 ppm in every case.

To gain insight into the air quality impact of SO_2 emissions from the black liquor holding pond at the ITT Mill, we calculated 1-hour SO_2 concentrations at the Third & Chestnut and Fourth & Baker monitors for wind directions varied at 1-degree intervals from 298 to 315 degrees. The wind direction that yielded the best correspondence between concurrent calculated (including background) and observed concentrations at Third & Chestnut during each of the 20 hours was assumed to be the effective transport wind direction, and the concentration calculated at the Fourth & Baker monitor for this wind direction was assumed to represent the contributions of the stack emissions and background to the observed concentration. For each hour, we then defined the difference between the observed concentration at Fourth & Baker and the estimated stack and background contributions as the concentration attributable to emissions from the holding pond. Finally, we used the short-term area source model described in Section A.3 of Appendix A to calculate the SO_2 emissions from the holding pond required to account for the concentrations estimated for the pond.

Table 3-4 lists, for each hour selected for model testing, the estimated transport wind direction, the corresponding 1-hour SO_2 concentrations calculated for the stack emissions and background at the Third & Chestnut and Fourth & Baker monitors, and the estimated SO_2 emission rate for the ITT holding pond. As shown by Table 3-4, the SO_2 emission rate estimated for the pond ranges from 3 to 105 grams per second and averages 29 grams per second. If Cases 10, 11 and 15 are deleted because of the possibility of low-level emissions not accounted for in the model calculations for these hours, the SO_2 emission rate estimated for the pond ranges from 3 to 48 grams per second and averages 23 grams per

TABLE 3-4

ESTIMATED WIND DIRECTIONS, CALCULATED CONCENTRATIONS AT THIRD & CHESTNUT AND FOURTH & BAKER ATTRIBUTABLE TO STACK EMISSIONS AND BACKGROUND, AND ESTIMATED HOLDING POND EMISSION RATES

Case	Estimated Wind Direction (deg)	Calculated Concentration* (ppm)		Estimated Holding Pond SO_2 Emission Rate (g/sec)
		Third & Chestnut	Fourth & Baker	
1	303	0.10	0.07	16
2	306	0.27	0.02	32
3	306	0.25	0.03	25
4	304	0.11	0.04	36
5	305	0.12	0.04	48
6	302	0.08	0.10	16
7	302	0.09	0.11	24
8	302	0.08	0.10	26
9	302	0.14	0.14	7
10	308	0.23	0.01	50
11	308	0.17	0.01	105
12	304	0.18	0.04	3
13	303	0.15	0.09	41
14	307	0.30	0.07	4
15	308	0.44	0.01	43
16	304	0.19	0.06	31
17	303	0.13	0.08	16
18	301	0.05	0.13	10
19	304	0.16	0.06	20
20	304	0.12	0.05	36
			Average Rate	29

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*The calculated concentrations include background (the concurrent SO_2 concentration measured at the Visitor Center).

second. The emission rates in Table 3-4 tend to support the belief of the Washington DOE that SO_2 emissions from the pond are highly variable.

SECTION 4

CALCULATION PROCEDURES AND RESULTS

4.1 THE ATTAINMENT STATUS ANALYSIS FOR THE EXISTING SOURCES

4.1.1 Annual Average Ground-Level SO_2 Concentrations

The long-term source inputs given in Section 2.1 for the ITT Rayonier and Crown Zellerbach Mills and the meteorological inputs discussed in Section 2.2.3 were used with the long-term concentration model (LONGZ) described in Section A.4 of Appendix A to calculate seasonal and annual average ground-level SO_2 concentrations for the Port Angeles area. The receptor grid consisted of 315 receptors spaced at 500-meter intervals over the 10-kilometer by 7-kilometer area covered by Figure 1-1. Additionally, discrete receptors were placed at the locations of the SO_2 air quality monitoring sites in the Port Angeles area (see Table 1-2) and at 100-meter intervals around the nearest boundary of Olympic National Park (the Visitor Center). The elevations of all receptors were extracted from USGS topographic maps, and the procedures described in Section A.5 of Appendix A were used to account for the effects of variations in terrain height over the receptor grid.

Figure 4-1 shows the calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the ITT Rayonier and Crown Zellerbach Mills. The maximum annual average concentration calculated in the vicinity of the ITT Mill of 32.0 micrograms per cubic meter is located at the Third & Chestnut monitor. This point, which is 720 meters southeast of the ITT Recovery Furnace stack, is 40 meters above plant grade. Similarly, the maximum annual average concentration calculated in the vicinity of the Crown Zellerbach Mill of 6.7 micrograms per cubic meter is located 715 meters east-southeast of the mill at a point that is in Port Angeles Harbor. The contributions of the individual sources to the maximum annual average concentrations calculated in the vicinity of the ITT and Crown Zellerbach Mills are listed in Tables 4-1 and 4-2, respectively.

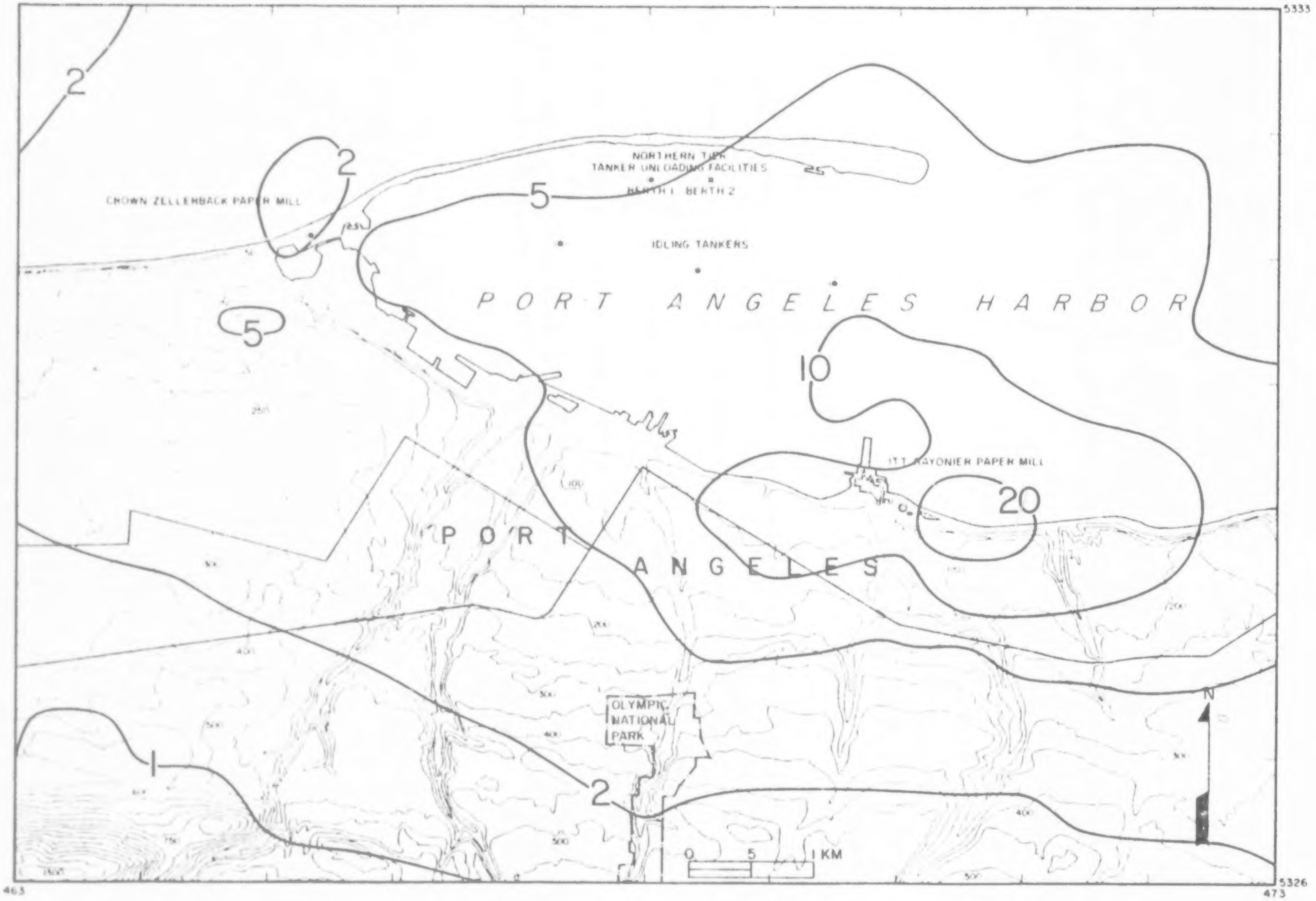


FIGURE 4-1. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the Crown Zellerbach and ITT Rayonier Mills.

TABLE 4-1

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM ANNUAL AVERAGE SO_2 CONCENTRATION CALCULATED IN THE VICINITY OF THE ITT RAYONIER MILL

Source	Concentration* (μg/m^3)
ITT Recovery Furnace	0.94
ITT West and East Vents (Acid Plant)	17.51
ITT North Bleach Vent	0.39
ITT South Bleach Vent	1.45
ITT Power Boiler No. 4	7.19
ITT Power Boiler No. 5	3.11
ITT H.F. Boiler No. 5	1.40
ITT Rayonier Total	31.99
Crown Zellerbach Total	0.48
Total for Existing Sources	32.47

*The UTM X and Y coordinates of the calculated concentrations are 470.30 and 5,328.74 kilometers, respectively. The receptor elevation is 40 meters MSL.

TABLE 4-2

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM ANNUAL AVERAGE SO_2 CONCENTRATION CALCULATED IN THE VICINITY OF THE CROWN ZELLERBACH MILL

Source	Concentration* ($\mu g/m^3$)
Crown Zellerbach H.F. Boiler No. 8	1.44
Crown Zellerbach Package Boiler	5.25
Crown Zellerbach Total	6.69
ITT Rayonier Total	2.07
Total for Existing Sources	8.75

*The UTM X and Y coordinates of the calculated concentrations are 466.00 and 5,331.00 kilometers, respectively. The receptor elevation is 0 meters MSL.

We point out that Figure 4-1 and Tables 4-1 and 4-2 do not include the effects of "background," which we define for the purpose of the attainment status analysis as ambient SO_2 concentrations attributable to emissions from sources other than the ITT Rayonier and Crown Zellerbach Mills. The only SO_2 air quality monitor for which sufficient meteorological data are available to estimate the annual background is the monitor at the Olympic National Park Visitor Center (see Figure 1-1). With south winds at the nearby BPA Substation meteorological tower, it is unlikely that emissions from the ITT and Crown Zellerbach Mills affect the Visitor Center monitor. The annual average SO_2 concentration at the Visitor Center monitor with south winds at the BPA tower is 3 micrograms per cubic meter. We conclude that the actual annual SO_2 background in the Port Angeles area is between 3 micrograms per cubic meter and the monitor's threshold concentration of about 13 micrograms per cubic meter. If the background is assumed to be 13 micrograms per cubic meter and is added to the maximum annual average concentration calculated for the combined emissions from the existing sources, the resulting maximum annual average concentration is 45.5 micrograms per cubic meter, or 57 percent of the annual National Ambient Air Quality Standard (NAAQS) for SO_2 of 80 micrograms per cubic meter.

4.1.2 Maximum Short-Term Ground-Level SO_2 Concentrations

A short-term NAAQS or Prevention of Significant Deterioration (PSD) Increment is violated at a given point during the second short-term period in a year with a short-term concentration above the corresponding NAAQS or PSD Increment. In general, the same definition of a violation of a short-term NAAQS or PSD Increment is applied to the results of dispersion model calculations. For example, the second-highest 24-hour average SO_2 concentration calculated for a receptor during a year normally is used to assess the compliance of the receptor with the 24-hour NAAQS for SO_2. However, if the EPA Regional Administrator identifies inadequacies in the data available for input to the dispersion model (for example, poorly defined emissions data or an insufficient period of record of meteorological data), the Administrator may specify that the highest rather than the highest of the second-highest short-term concentrations calculated for all receptors be used to evaluate compliance with the short-term NAAQS and PSD Increments. As of 18 November 1980, the Administrator of EPA Region 10 had not made any determination about the adequacy of the emissions and meteorological data available for the Port Angeles area. Consequently, this report considers both the highest and the highest, second-highest calculated short-term concentrations in evaluating compliance with the short-term NAAQS and PSD Increments.

The 1-hour, 3-hour and 24-hour average ground-level SO_2 concentrations given below are for the the combinations of meteorological and topographic conditions that maximize the 1-hour, 3-hour and 24-hour average ground-level concentrations calculated following the short-term modeling procedures outlined in Sections A.3 and A.5 of Appendix A. Also, as discussed in Section 2.2.2, these conditions are associated with the highest observed short-term concentrations in the Port Angeles area.

24-Hour Average Concentrations

For stacks located in flat terrain, both theory (Pasquill, 1974 and others) and air quality data (Gorr and Dunlap, 1977 and others) indicate that the highest 24-hour average ground-level concentrations occur during periods of persistent moderate-to-strong winds in combination with neutral stability. Additionally, following the short-term modeling procedures outlined in Sections A.3 and A.5 of Appendix A, the highest 24-hour average ground-level concentrations calculated for stack emissions usually occur when persistent moderate-to-strong winds blow toward nearby elevated terrain. We therefore used our persistence search (PRSIST) data analysis program with the 15 August 1978 to 15 August 1979 Ediz Hook 10-meter tower wind data to isolate all periods when winds above 1.5 meters per second persisted within any 25-degree sector for 12 or more hours. From the 120 cases (including overlapping periods), we selected 18 calendar days for use in our short-term model calculations. (We used calendar days rather than running mean "worst-case" 24-hour periods for consistency with the models recommended for use in the absence of complicating factors by the EPA Guideline on Air Quality Models.)

Table 4-3 gives the means and standard deviations of the hourly wind-direction and wind-speed observations for the 18 "worst-case" days. Cases 5, 7, 9, 10, 11 and 13 were selected because the wind direction persisted within a narrow angular sector throughout each day. As shown by Table 4-3, these days have the lowest standard deviations of the hourly wind-direction observations. Additionally, these days tend to have the highest 24-hour average wind speeds. The remaining days in Table 4-3 were selected because of high occurrence frequencies of the onshore wind directions required to maximize the effects of elevated terrain on the calculated concentrations. As expected on the basis of the analyses of meteorological and air quality data described in Section 2.2, the majority of the "worst-case" days identified by the PRSIST program are in the summer months.

Table 4-4 lists, for each of the SO_2 air quality monitoring sites in the Port Angeles area (see Figure 1-1), the observed 24-hour average SO_2 concentrations during the 18 "worst-case" days. The observed 24-hour average concentrations at the Olympic National Park Visitor Center and at the City Light Building are low, a result that is consistent with the wind directions during the 18 days. However, the wind directions during every day except 10 November 1978 (Case 2) indicate that emissions from the ITT Rayonier Mill probably affected the air quality in the area east-southeast of the mill. Although no SO_2 concentration data are available for the Fourth & Baker and Third & Chestnut monitors for many of these days, the observed 24-hour average SO_2 concentrations for the

TABLE 4-3

MEANS AND STANDARD DEVIATIONS OF THE HOURLY WIND-DIRECTION AND WIND-SPEED OBSERVATIONS ON THE "WORST-CASE" DAYS

24-Hour Case No.	Date	Wind Direction (deg)		Wind Speed (m/sec)	
		Mean	Std. Deviation	Mean	Std. Deviation
1	21 Aug 78	294	17	4.1	2.5
2	10 Nov 78	066	61	6.6	2.7
3	24 Mar 79	280	18	7.5	1.4
4	6 Apr 79	278	15	7.8	1.9
5	29 Apr 79	279	6	6.6	1.5
6	26 May 79	289	14	7.9	3.3
7	3 Jun 79	279	6	8.3	1.2
8	8 Jun 79	288	17	4.9	1.8
9	10 Jun 79	283	7	8.6	1.1
10	26 Jun 79	279	7	8.5	2.2
11	28 Jun 79	276	5	7.7	2.6
12	19 Jul 79	291	13	5.3	1.9
13	21 Jul 79	286	7	6.8	1.7
14	22 Jul 79	288	15	5.6	2.1
15	24 Jul 79	290	11	5.7	1.8
16	25 Jul 79	288	8	6.7	1.6
17	2 Aug 79	289	16	5.6	1.5
18	8 Aug 79	287	15	5.6	1.6

TABLE 4-4

OBSERVED 24-HOUR AVERAGE CONCENTRATIONS ON THE "WORST-CASE" DAYS

24-Hour Case No.	Date	Observed 24-Hour SO_2 Concentration ($\mu g/m^3$)			
		Visitor Center	Fourth & Baker	Third & Chestnut	City Light Bldg.
1	21 Aug 78	13	MSG	MSG	5
2	10 Nov 78	8	MSG	MSG	MSG
3	24 Mar 79	MSG	MSG	MSG	29
4	6 Apr 79	0	MSG	MSG	26
5	29 Apr 79	0	168	MSG	MSG
6	26 May 79	3	147	MSG	24
7	3 Jun 79	0	152	MSG	21
8	8 Jun 79	26	84	210	MSG
9	10 Jun 79	0	236	MSG	MSG
10	26 Jun 79	0	186	MSG	MSG
11	28 Jun 79	MSG	MSG	MSG	26
12	19 Jul 79	29	178	MSG	5
13	21 Jul 79	0	123	MSG	0
14	22 Jul 79	3	134	MSG	26
15	24 Jul 79	5	165	MSG	MSG
16	25 Jul 79	3	160	MSG	MSG
17	2 Aug 79	0	155	296	MSG
18	8 Aug 79	3	152	128	MSG

remaining days are relatively high. Thus, the SO_2 concentration measurements made in the area east-southeast of the ITT Mill tend to support the selection of the "worst-case" days. (We point out that direct comparisons of the calculated 24-hour average concentrations given in this section with the observed concentrations in Table 4-4 should not be made because the SO_2 emissions assumed in the model calculations for the ITT Rayonier and Crown Zellerbach Mills do not necessarily correspond to the actual emissions during the "worst-case" days.)

We used the 24-hour source inputs given in Section 2.1 for the ITT Rayonier and Crown Zellerbach Mills and the hourly meteorological inputs listed in Appendix B for the 18 "worst-case" days with the short-term concentration model (SHORTZ) described in Sections A.3 and A.5 of Appendix A to calculate 24-hour average ground-level SO_2 concentrations for each of the "worst-case" days. Two receptor arrays in polar coordinates were used in the model calculations. The first receptor array was centered at the Crown Zellerbach Mill; the Universal Transverse Mercator (UTM) X and Y coordinates of the origin were 465.30 and 5,331.15 kilometers, respectively. Receptors were placed at distances from the stacks of 0.4, 0.7, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 kilometers; the angular spacing between receptors was 5 degrees. The second receptor array was identical to the first receptor array except that the origin was placed at the center of the plant production area of the ITT Rayonier Mill. The UTM X and Y coordinates of the origin of the second array were 469.74 and 5,329.19 kilometers, respectively. For each receptor array, the elevations of all receptors were extracted from USGS topographic maps, and the procedures outlined in Section A.5 in Appendix A were used to account for the effects of variations in the terrain height on ground-level concentrations.

The results of the 24-hour average SO_2 concentration calculations for the ITT Rayonier and Crown Zellerbach Mills are summarized in Table 4-5 and 4-6, respectively. The background concentration shown for

TABLE 4-5

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE ITT RAYONIER MILL

24-Hour Case No.	Concentration ($\mu g/m^3$)				Location*		
	ITT	Crown Zellerbach	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	522	18	13	553	1.0	115	47
2	581	12	13	606	0.4	220	23
3	323	6	13	341	0.7	120	40
4	243	4	13	260	0.7	120	40
5	298	1	13	311	0.7	100	0
6	437	6	13	457	0.7	120	40
7	320	1	13	334	0.7	100	0
8	231	3	26	260	0.7	125	40
9	273	3	13	289	0.7	100	0
10	256	2	13	271	0.7	095	0
11	275	0	13	288	0.7	100	0
12	467	6	29	502	0.7	120	40
13	262	5	13	280	1.0	115	47
14	245	3	13	261	0.7	125	40
15	421	4	13	439	0.7	120	40
16	272	4	13	289	0.7	120	40
17	325	4	13	341	0.7	120	40
18	198	1	13	212	0.7	130	40

*Locations are with respect to the point with UTM coordinates X = 469.74 kilometers, Y = 5,329.19 kilometers.

TABLE 4-6

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE CROWN ZELLERBACH MILL

24-Hour Case No.	Concentration ($\mu g/m^3$)				Location*		
	Crown Zellerbach	ITT	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	80	0	13	93	1.0	120	0
2	292	0	13	305	0.7	220	57
3	81	0	13	94	0.7	110	0
4	83	0	13	96	0.7	115	0
5	176	0	13	189	0.7	100	0
6	98	0	13	111	0.7	120	0
7	208	0	13	221	0.7	100	0
8	68	0	26	94	0.7	125	0
9	183	0	13	196	0.7	100	0
10	182	0	13	195	0.7	95	0
11	187	0	13	200	0.7	100	0
12	100	0	29	129	0.7	120	0
13	147	0	13	160	0.7	105	0
14	72	0	13	85	0.7	125	0
15	81	0	13	94	0.7	120	0
16	122	0	13	135	0.7	110	0
17	73	0	13	86	0.7	125	0
18	77	0	13	90	0.7	125	0

*Locations are with respect to the point with UTM coordinates X = 465.30 kilometers, Y = 5,331.15 kilometers.

each day in the two tables is the maximum of the SO_2 monitor threshold of 13 micrograms per cubic meter and the 24-hour average SO_2 concentration measured at the Visitor Center. The maximum 24-hour average concentrations calculated for both mills occur on 10 November 1978 (Case 2), a day with persistent northeast winds. Figure 4-2 shows the calculated isopleths of 24-hour average ground-level SO_2 concentration for 10 NOvember 1978. (Figure 4-2 does not include any background estimate.) The maximum 24-hour concentration calculated southwest of the ITT MIll (606 micrograms per cubic meter with background included) is almost entirely determined by emissions from the ITT Mill and the maximum 24-hour concentration calculated southwest of the Crown Zellerbach Mill (305 micrograms per cubic meter with background included) is entirely determined by emissions from the Crown Zellerbach Mill. Table 4-7 gives the contributions of the individual sources at the ITT and Crown Zellerbach Mills to the calculated maximum 24-hour concentrations.

The 24-hour NAAQS for SO_2 is 365 micrograms per cubic meter. As shown by Table 4-5, there are five days with calculated maximum 24-hour average SO_2 concentrations above 365 micrograms per cubic meter attriutable to emissions from the ITT Rayonier Mill (Cases 1, 2, 6, 12 and 15). The maximum 24-hour concentration for one of these days is calculated to occur southwest of the ITT MIll, while the maximum 24-hour concentrations for the four other days are calculated to occur east-southeast of the mill. Thus, if it is assumed that any calculated concentration above 365 micrograms per cubic meter is a violation of the 24-hour NAAQS, the results of the model calculations indicate that non-attainment areas for the 24-hour NAAQS are located southwest and east-southeast of the ITT MIll. However, if it is assumed that the 24-hour standard is violated at a given point on the second day during a year with a calculated 24-hour average concentration above 365 micrograms per cubic meter, the results of the model calculations indicate that the only non-attainment area for the 24-hour NAAQS is located east-southeast of the ITT MIll. To define the boundaries of the calculated non-attainment area(s) for the 24-hour NAAQS, we repeated our

TABLE 4-7

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE ITT RAYONIER MILL AND CROWN ZELLERBACK MILL

Source	Concentration (μg/m^3)
(a) ITT Rayonier Mill	
Recovery Furnace	0
West and East Vents (Acid Plant)	171
North Bleach Vent	5
South Bleach Vent	18
Power Boiler No. 4	367
Power Boiler No. 5	19
H.F. Boiler No. 5	0
ITT Rayonier Total	581
(b) Crown Zellerbach Mill	
H.F. Boiler No. 8	236
Package Boiler	55
Crown Zellerbach Total	292

dispersion model calculations for Cases 1, 2, 6, 12 and 15 using a more detailed receptor grid. Specifically, the angular spacing of receptors southwest and east-southeast of the ITT MIll was reduced from 5 degrees to 2.5 degrees and additional receptor distances of 0.5, 0.6, 0.7, 0.8, 0.9, 1.1, 1.2, 1.3 and 1.4 kilometers were added.

Figure 4-3 (a) shows the calculated non-attainment areas for the 24-hour NAAQS for SO_2 that are defined by the receptors with one or more calculated 24-hour average SO_2 concentrations (including background) above 365 micrograms per cubic meter. Similarly, Figure 4-3 (b) shows the calculated non-attainment area for the 24-hour NAAQS that is defined by the receptors with two or more calculated 24-hour average SO_2 concentrations (including background) above 365 micrograms per cubic meter. We point out that the calculated non-attainment areas consider only the effects of stack emissions. As discussed in Sections 2.1 and 3, the black liquor holding pond at the ITT MIll is believed to have a variable, but sometimes significant, impact on SO_2 air quality in the vicinity of the mill. (The holding pond is irregularly-shaped ellipse north of the Third & Chestnut monitor and the non-attainment area in Figure 4-3 (b).) Thus, if the effects of emissions from the holding pond are considered, the actual non-attainment area(s) may be somewhat larger than indicated in Figures 4-3 (a) and 4-3 (b).

It is important to note that persistant winds from the west-northwest are required for the occurrence of calculated 24-hour average SO_2 concentrations above the 24-hour NAAQS in the area east-southeast of the ITT MIll. As indicated by Table 2-15 in Section 2.2, the winds near this calculated non-attainment area tend to be from the west-northwest when the winds at Ediz Hook are from the west. Because the Ediz Hook 10-meter tower wind data were used in the dispersion model calculations, it follows that we may have underestimated the frequency of occurrence of 24-hour concentrations above the 24-hour NAAQS in the area east-southeast of the ITT Mill. However, we believe that the maximum 24-hour

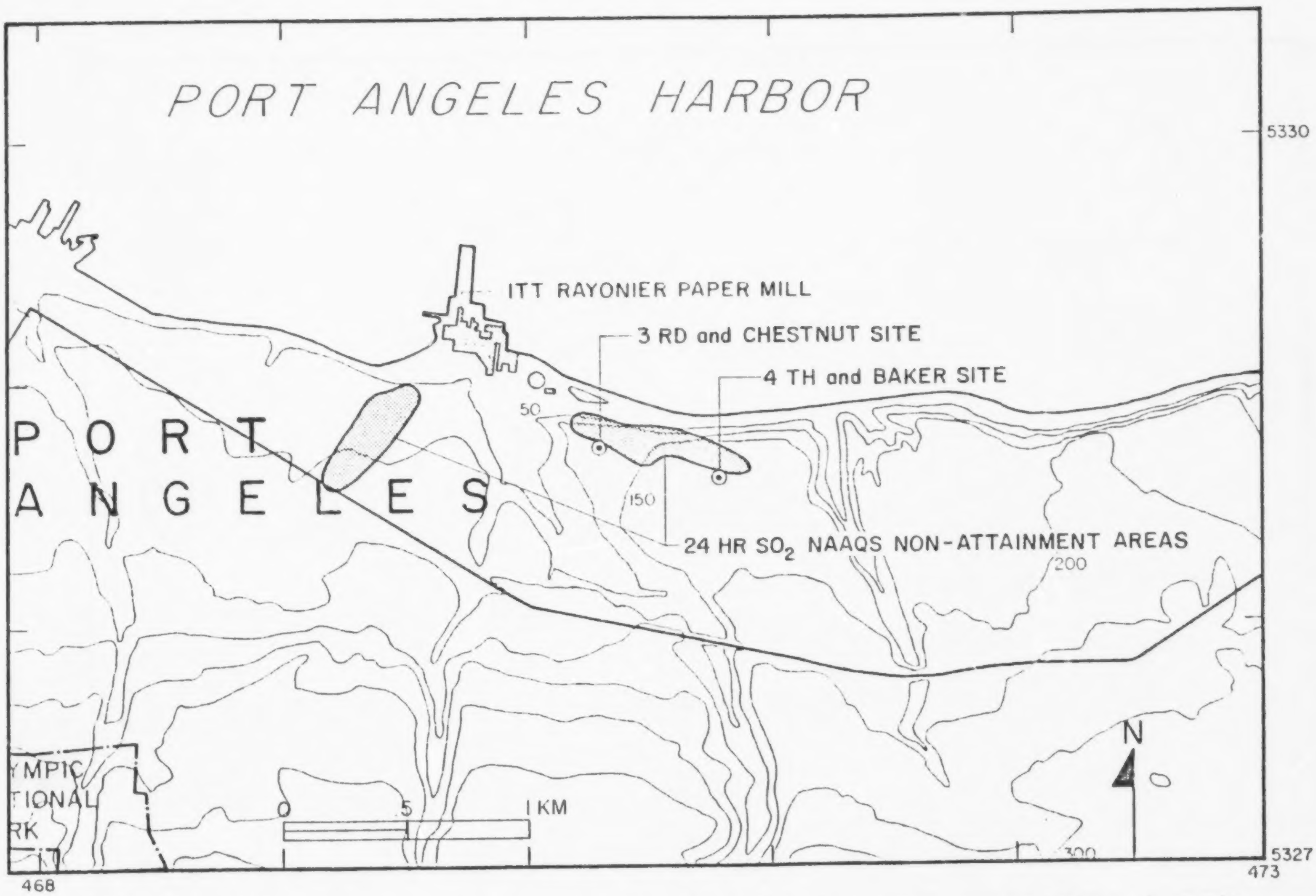


FIGURE 4-3 (a). Illustration of the two areas within which 24-hour average concentrations above the 24-hour National Ambient Air Quality Standard (NAAQS) for SO_2 are calculated to occur one or more times per year. The area within which 3-hour average concentrations above the 3-hour NAAQS are calculated to occur once per year is entirely contained within the area east-southeast of the ITT Mill.

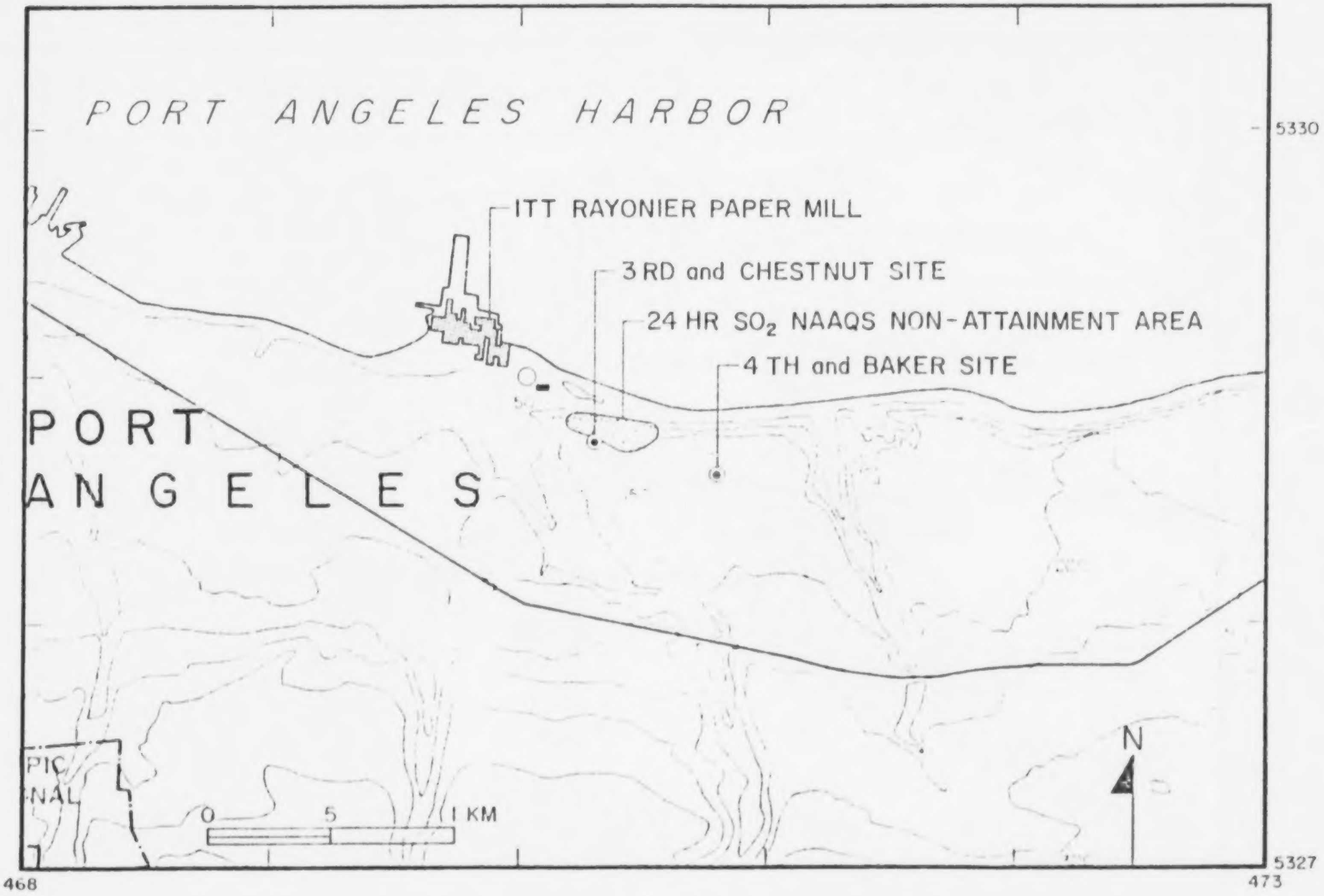


FIGURE 4-3 (b). Illustration of the area within which 24-hour average concentrations above the 24-hour National Ambient Air Quality Standard (NAAQS) for SO_2 are calculated to occur two or more times per year.

concentration that we calculated for this area of 553 micrograms per cubic meter (Case 1) probably is representative of the maximum 24-hour concentration that can be expected to occur for the emissions assumed in the model calculations.

3-Hour Average Concentrations

High 3-hour average ground-level concentrations attributable to stack emissions are associated with periods of persistent moderate-to-strong winds, periods of transition from a stable thermal stratification to an unstable thermal stratification or vice versa, and periods of limited mixing. As discussed in Section 2.2.2, these meteorological conditions are associated with the highest observed 1-hour SO_2 concentrations in the Port Angeles area. Consequently, all three critical meteorological regimes were considered in our short-term model calculations of maximum 3-hour SO_2 concentrations.

The 18 "worst-case" days discussed above contained 15 "clock-hour" 3-hour periods when the wind persisted within a 5-degree sector for all 3 hours. (As in the case of the 24-hour concentration calculations, we used "clock hours" (0100 through 0300, 0400 through 0600, etc.) in our 3-hour concentration calculations for consistency with standardized EPA dispersion models.) Additionally, we used our PRSIST program to identify all 3-hour ("clock-hour") periods with wind speeds between 1.5 and 5.0 meters per second at the Ediz Hook tower and wind directions within a single 5-degree sector for all 3 hours. The 22 3-hour cases identified in our second PRSIST analysis in combination with the 15 cases for the 18 "worst-case" days yielded a total of 37 "worst-case" 3-hour periods.

Table 4-8 identifies the "worst-case" 3-hour periods and gives, for each period, the 3-hour mean wind direction and speed and the Pasquill stability category for each hour of the period. As shown by

TABLE 4-8

AVERAGE WIND DIRECTIONS AND WIND SPEEDS AND THE PASQUILL STABILITY CATEGORIES DURING THE "WORST-CASE" 3-HOUR PERIODS

3-Hour Case No.	Date	Hours (PST)	3-Hour Average Wind		Pasquill Stability Category		
			Direction (deg)	Speed (m/sec)	Hr.1	Hr.2	Hr.3
1	23 Aug 78	1600-1800	290	2.2	D	D	D
2	13 Nov 78	0100-0300	220	2.8	F	F	E
3	12 Dec 78	1900-2100	155	3.1	E	F	F
4	19 Dec 78	0100-0300	215	3.6	D	E	E
5	20 Dec 78	0700-0900	245	2.9	D	D	D
6	3 Jan 79	0100-0300	165	2.8	F	F	F
7	5 Jan 79	2200-2400	170	3.4	E	E	F
8	19 Jan 79	1600-1800	090	3.1	D	D	D
9	27 Jan 79	0100-0300	270	3.9	D	D	D
10	1 Mar 79	0100-0300	240	3.6	D	D	E
11	24 Mar 79	1300-1500	285	9.2	D	D	D
12	2 Apr 79	0400-0600	270	3.6	D	D	D
13	6 Apr 79	1600-1800	295	11.0	D	D	D
14	22 Apr 79	1000-1200	125	2.0	B	B	B
15	29 Apr 79	0400-0600	270	4.4	E	D	D
16	1 May 79	0700-0900	280	4.2	D	D	D
17	7 May 79	1000-1200	050	2.4	B	B	B
18	3 Jun 79	1900-2100	275	7.4	D	D	D
19	10 Jun 79	0400-0600	280	6.7	D	D	D
20	10 Jun 79	1600-1800	280	9.9	D	D	D
21	10 Jun 79	2200-2400	275	8.6	D	D	D
22	18 Jun 79	0400-0600	270	4.0	D	D	D
23	20 Jun 79	0400-0600	245	4.5	D	D	D
24	22 Jun 79	1000-1200	285	3.6	D	B	B
25	26 Jun 79	1600-1800	275	10.9	D	D	D
26	26 Jun 79	1900-2100	275	10.4	D	D	D
27	28 Jun 79	1000-1200	280	6.9	D	D	D
28	28 Jun 79	1900-2100	275	10.3	D	D	D
29	29 Jun 79	0700-0900	260	3.9	D	D	D
30	29 Jun 79	1000-1200	265	3.1	D	D	D
31	8 Jul 79	1600-1800	250	3.4	C	D	D
32	19 Jul 79	0100-0300	275	5.9	D	D	D
33	21 Jul 79	0100-0300	280	8.5	D	D	D
34	2 Aug 79	1300-1500	300	5.7	C	C	D
35	2 Aug 79	2200-2400	280	6.1	D	D	D
36	8 Aug 79	1000-1200	310	3.7	B	B	C
37	8 Aug 79	2200-2400	280	5.5	D	D	D

the table, the Pasquill stability categories during our selected 3-hour periods ranged from the very stable F category to the unstable B category. The stable categories are restricted to hours with offshore wind directions, while the unstable categories generally occur with onshore wind directions. However, the majority of the hours are associated with the neutral D category with winds from the west or west-northwest.

Table 4-9 gives the 3-hour average SO_2 concentrations measured at the various monitoring sites in the Port Angeles area during the "worst-case" 3-hour periods. In general, the observed 3-hour SO_2 concentrations are low at all monitors except the Fourth & Baker monitor and/or the Third & Chestnut monitor during periods with the west-northwest winds required to transport emissions from the ITT Rayonier Mill to these monitors. With the exception of Case 17, the Ediz Hook tower wind directions indicate that the Visitor Center monitor was unaffected by SO_2 emissions from the existing sources. Because the observed 3-hour average concentrations at the Visitor Center were below the monitor's threshold of about 13 micrograms per cubic meters for all cases except Case 17, we assumed a background of 13 micrograms per cubic meter for these cases. The wind direction for Case 17 of 050 degrees indicates that the merged plume from the ITT Mill might have followed a nearly straight-line trajectory to the Visitor Center. However, the 3-hour concentration observed at the Fourth & Baker monitor during Case 17 of 188 micrograms per cubic meter is almost identical to the corresponding concentration observed at the Visitor Center of 170 micrograms per cubic meter. Additionally, no SO_2 sources are located upwind of Fourth & Baker with northeast winds. Thus, it appears that an almost uniform background concentration existed in the Port Angeles area during Case 17. We therefore assumed that the 3-hour concentration at the Visitor Center of 170 micrograms per cubic meter was representative of the background in the Port Angeles area during Case 17. The fact that Case 17 was preceded by a number of hours with light winds from the south and south-

TABLE 4-9

OBSERVED 3-HOUR AVERAGE SO_2 CONCENTRATIONS FOR THE "WORST-CASE" 3-HOUR PERIODS

3-Hour Case No.	Date	Hours (PST)	Observed 3-Hour SO_2 Concentration ($\mu g/m^3$)			
			Visitor Center	Fourth & Baker	Third & Chestnut	City Light Bldg.
1	23 Aug 78	1600-1800	0	MSG	MSG	26
2	13 Nov 78	0100-0300	0	MSG	MSG	MSG
3	12 Dec 78	1900-2100	0	MSG	MSG	52
4	19 Dec 78	0100-0300	0	MSG	MSG	26
5	20 Dec 78	0700-0900	0	MSG	MSG	26
6	3 Jan 79	0100-0300	0	MSG	MSG	35
7	5 Jan 79	2200-2400	0	MSG	MSG	MSG
8	19 Jan 79	1600-1800	0	MSG	MSG	44
9	27 Jan 79	0100-0300	0	MSG	MSG	26
10	1 Mar 79	0100-0300	0	MSG	MSG	MSG
11	24 Mar 79	1300-1500	MSG	MSG	MSG	26
12	2 Apr 79	0400-0600	0	MSG	MSG	26
13	6 Apr 79	1600-1800	0	MSG	MSG	26
14	22 Apr 79	1000-1200	13	0	MSG	MSG
15	29 Apr 79	0400-0600	0	0	MSG	MSG
16	1 May 79	0700-0900	0	35	MSG	MSG
17	7 May 79	1000-1200	170	188	MSG	MSG
18	3 Jun 79	1900-2100	0	44	MSG	26
19	10 Jun 79	0400-0600	0	4	MSG	MSG
20	10 Jun 79	1600-1800	0	358	MSG	MSG
21	10 Jun 79	2200-2400	0	0	MSG	MSG
22	18 Jun 79	0400-0600	0	0	MSG	MSG
23	20 Jun 79	0400-0600	0	0	MSG	0
24	22 Jun 79	1000-1200	MSG	122	MSG	0
25	26 Jun 79	1600-1800	0	410	MSG	MSG
26	26 Jun 79	1900-2100	0	144	MSG	MSG
27	28 Jun 79	1000-1200	MSG	218	MSG	26
28	28 Jun 79	1900-2100	0	122	MSG	26
29	29 Jun 79	0700-0900	0	26	MSG	26
30	29 Jun 79	1000-1200	0	52	MSG	26
31	8 Jul 79	1600-1800	0	218	MSG	26
32	19 Jul 79	0100-0300	0	13	MSG	0
33	21 Jul 79	0100-0300	0	20	MSG	0
34	2 Aug 79	1300-1500	0	432	480	MSG
35	2 Aug 79	2200-2400	0	0	0	MSG
36	8 Aug 79	1000-1200	4	13	262	MSG
37	8 Aug 79	2200-2400	0	13	0	MSG

southwest suggests that SO_2 previously emitted from the ITT Mill was advected back over Port Angeles and caused this background concentration.

We used the 3-hour source inputs given in Section 2 for the ITT Rayonier and Crown Zellerbach Mills and the hourly meteorological inputs listed in Appendix B for the 37 "worst-case" 3-hour periods with the SHORTZ program to calculate 3-hour average ground-level SO_2 concentrations for each of the "worst-case" 3-hour periods. The calculation procedures and receptor grids were identical to those described above in the discussion of the 24-hour average concentration calculations.

The results of the 3-hour average SO_2 concentration calculations for the ITT Rayonier and Crown Zellerbach Mills are given in Tables 4-10 and and 4-11, respectively. Excluding background, the maximum 3-hour concentration calculated for the ITT Mill is 1,424 micrograms per cubic meter (Case 34) and the maximum 3-hour concentration calculated for the Crown Zellerbach Mill is 461 micrograms per cubic meter (Case 17). Both of these calculated maximum 3-hour concentrations occur on elevated terrain about 40 meters above plant grade. If the effects of background and emissions from the Crown Zellerbach Mill are included, the maximum 3-hour concentration calculated in the vicinity of the ITT Mill is 1,442 micrograms per cubic meter. Similarly, the maximum 3-hour concentration calculated in the vicinity of the Crown Zellerbach Mill is 631 micrograms per cubic meter if the effects of background are included. The calculated isopleths of maximum 3-hour average SO_2 concentration attributable to emissions from the ITT and Crown Zellerbach Mills are shown in Figures 4-4 and 4-5, respectively. (Figures 4-4 and 4-5 do not include background.) The contributions of the individual sources to the maximum 3-hour concentrations calculated for the two mills are listed in Table 4-12.

The 3-hour NAAQS for SO_2 is 1,300 micrograms per cubic meter. If any calculated 3-hour average concentration above 1,300 micrograms per

TABLE 4-10

MAGNITUDES AND LOCATIONS OF MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE ITT RAYONIER MILL

3-Hour Case No.	Concentration ($\mu g/m^3$)				Location*		
	ITT	Crown Zellerbach	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	1,156	33	13	1,202	1.2	110	46
2	540	0	13	553	2.0	040	0
3	460	0	13	473	1.5	335	0
4	496	0	13	509	1.5	035	0
5	400	0	13	413	1.2	065	0
6	460	0	13	473	2.0	345	0
7	494	0	13	507	2.0	350	0
8	584	0	13	597	0.8	270	16
9	434	0	13	447	1.2	090	0
10	528	0	13	541	1.5	060	0
11	564	1	13	577	0.7	105	0
12	441	0	13	454	1.2	090	0
13	853	12	13	878	0.9	115	37
14	463	0	13	476	0.4	305	0
15	512	0	13	525	1.2	090	0
16	515	0	13	528	2.0	100	46
17	694	0	170	864	0.4	230	22
18	659	0	13	672	0.7	095	0
19	606	0	13	619	0.8	100	0
20	539	0	13	552	0.7	100	0
21	588	0	13	601	0.7	095	0
22	456	0	13	469	1.2	090	0
23	452	0	13	465	1.0	065	0
24	460	3	13	476	1.5	105	35
25	511	0	13	524	0.7	095	0
26	523	0	13	536	0.7	095	0
27	567	0	13	580	0.8	100	0
28	529	0	13	542	0.7	095	0
29	456	0	13	469	1.2	030	0
30	475	0	13	488	1.2	085	0
31	657	0	13	670	0.5	070	0
32	533	0	13	546	0.8	095	0
33	604	0	13	617	0.7	100	0
34	1,424	5	13	1,442	0.7	120	40
35	559	0	13	572	0.9	100	0
36	1,010	1	13	1,024	0.6	130	38
37	406	0	13	419	0.8	100	0

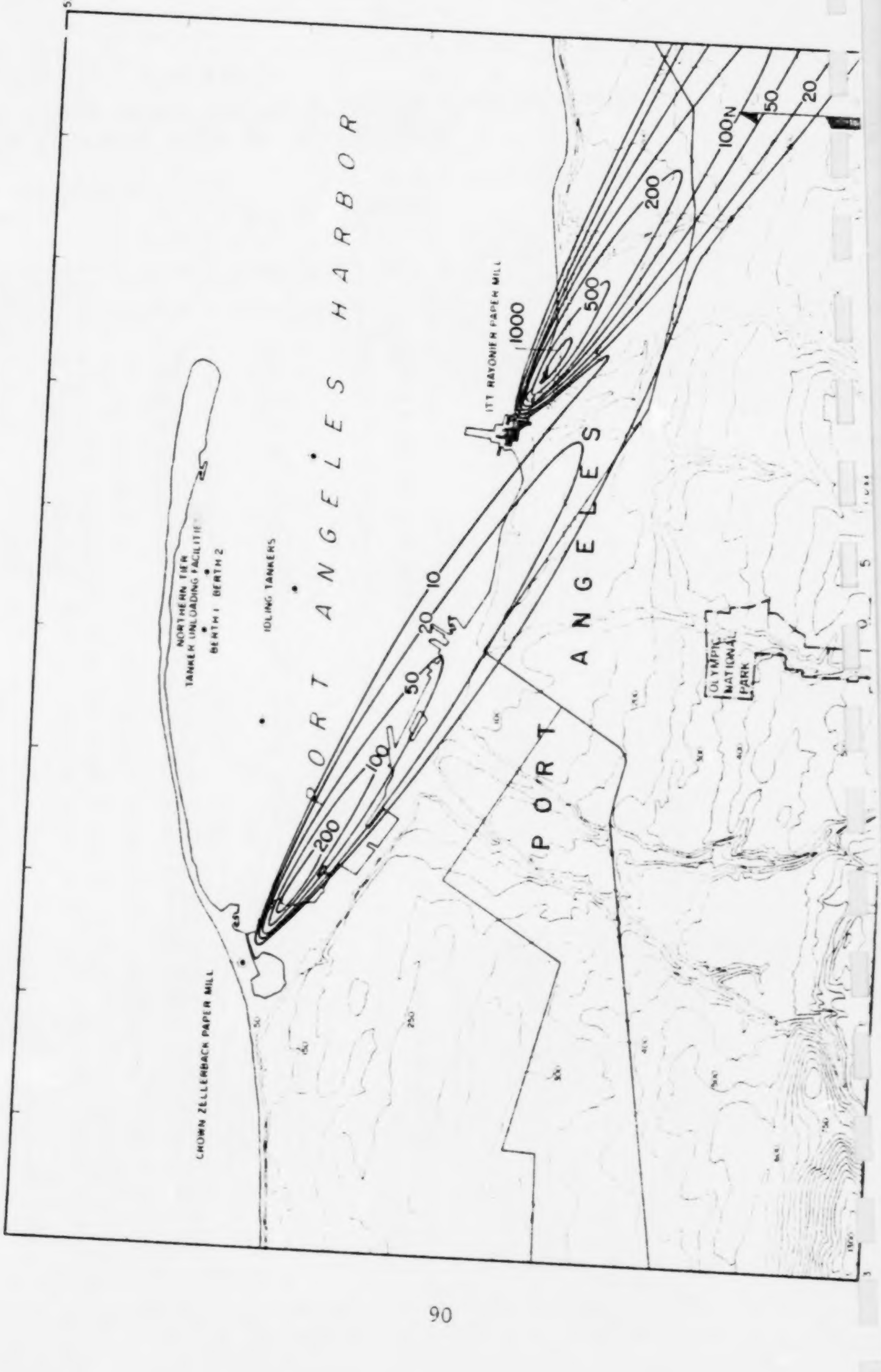
*Locations are with respect to the point with UTM coordinates X = 469.74 kilometers, Y = 5,329.19 kilometers.

TABLE 4-11

MAGNITUDES AND LOCATIONS OF MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE CROWN ZELLERBACH MILL

3-Hour Case No.	Concentration ($\mu g/m^3$)				Location *		
	Crown Zellerbach	ITT	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	242	0	13	255	1.5	110	0
2	279	0	13	292	2.5	040	0
3	279	0	13	292	2.5	335	0
4	274	0	13	287	1.5	035	0
5	290	0	13	303	1.5	065	0
6	263	0	13	276	2.5	345	0
7	262	0	13	275	2.0	350	0
8	29	0	13	42	1.2	270	0
9	241	0	13	254	1.2	090	0
10	266	0	13	279	1.5	060	0
11	379	0	13	392	0.6	105	0
12	244	0	13	257	1.2	090	0
13	408	0	13	421	0.6	115	0
14	217	0	13	230	0.7	305	0
15	279	0	13	292	1.2	090	0
16	252	0	13	265	1.2	100	0
17	461	0	170	631	0.6	230	43
18	310	0	13	323	0.7	095	0
19	289	0	13	302	0.8	100	0
20	416	0	13	429	0.6	100	0
21	358	0	13	371	0.7	095	0
22	254	0	13	267	1.2	090	0
23	253	0	13	266	1.2	065	0
24	202	0	13	215	0.9	105	0
25	415	0	13	428	0.6	095	0
26	421	0	13	434	0.6	095	0
27	296	0	13	309	0.8	100	0
28	411	0	13	424	0.6	095	0
29	255	0	13	268	1.2	080	0
30	245	0	13	258	1.5	085	0
31	274	0	13	287	1.2	070	0
32	263	0	13	276	0.9	095	0
33	352	0	13	365	0.7	100	0
34	301	0	13	314	0.7	120	0
35	282	0	13	295	0.9	100	0
36	263	0	13	276	0.6	130	0
37	87	0	13	100	0.8	100	0

*Locations are with respect to the point with UTM coordinates X = 465.30 kilometers, Y = 5,331.15 kilometers.


5333
PORT ANGELES HARBOR
NORTHERN TIER TANKER UNLOADING FACILITIES
BERTH 1
BERTH 2
IDLING TANKERS
CROWN ZELLERBACK PAPER MILL
ITT RAYONIER PAPER MILL
PORT ANGELES
OLYMPIC NATIONAL PARK
1000
500
200
100N
100
50
20
10
0
5

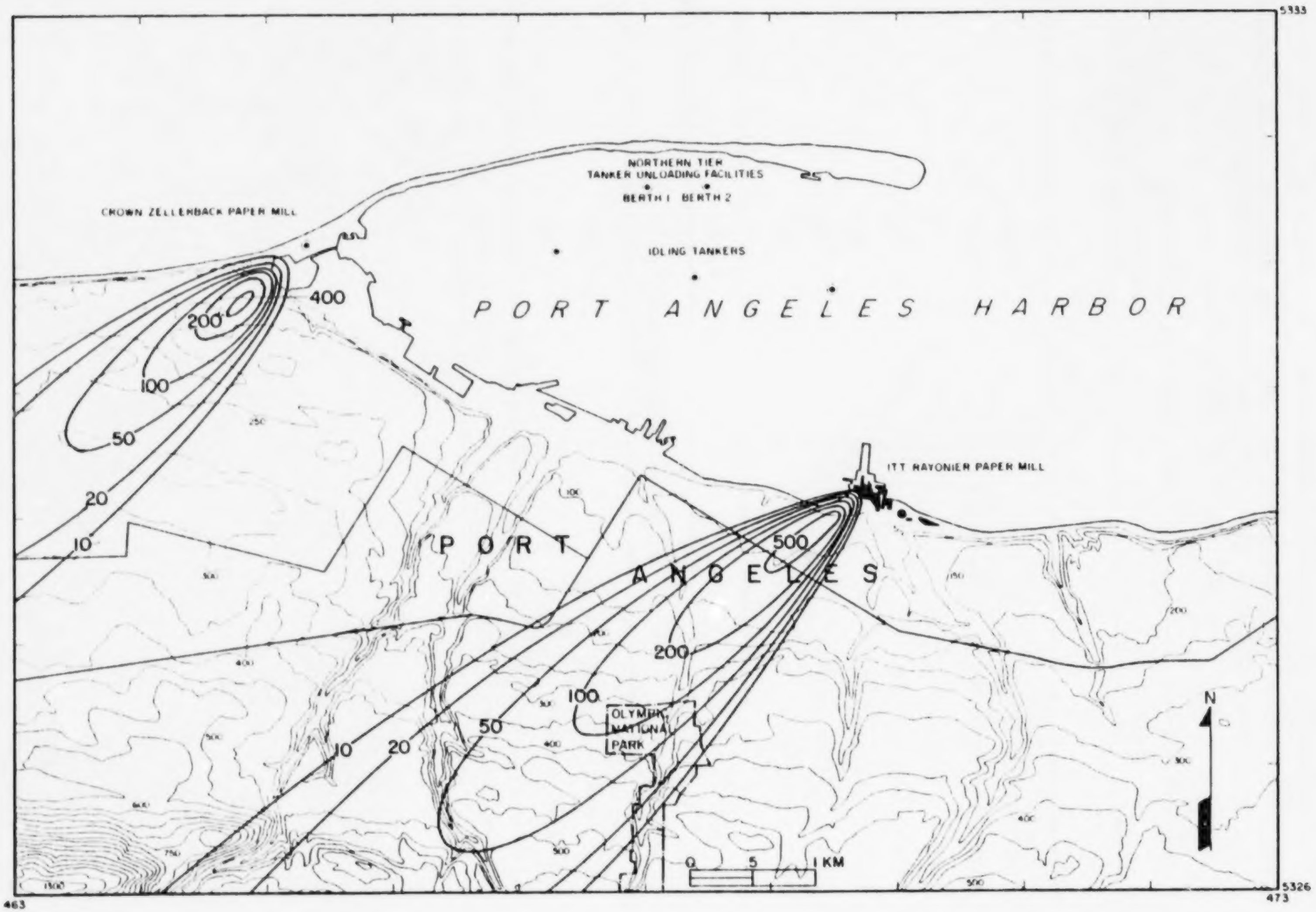


FIGURE 4-5. Calculated isopleths of 3-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the Crown Zellerbach Mill and ITT Rayonier Mill during the "worse-case" 3-hour period (1000 through 1200 PST on 7 May 1979) for emissions from the Crown Zellerback Mill.

TABLE 4-12

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE ITT RAYONIER MILL AND CROWN ZELLERBACK MILL

Source	Concentration ($\mu g/m^3$)
(a) ITT Rayonier Mill	
Recovery Furnace	33
West and East Vents (Acid Plant)	457
North Bleach Vent	9
South Bleach Vent	31
Power Boiler No. 4	493
Power Boiler No. 5	384
H.F. Boiler No. 5	17
ITT Rayonier Total	1,424
(b) Crown Zellerbach Mill	
H.F. Boiler No. 8	369
Package Boiler	92
Crown Zellerbach Total	461

cubic meter is defined as a violation of the 3-hour NAAQS, a non-attainment area for the 3-hour NAAQS is located east-southeast of the ITT Rayonier Mill. As indicated by Figure 4-4, this non-attainment area for the 3-hour NAAQS is very small and is entirely contained within the non-attainment area for the 24-hour NAAQS that is shown east-southeast of the ITT Mill in Figure 4-3 (a). If it is assumed that the 3-hour standard is violated at a given point during the second 3-hour period in a year with a calculated 3-hour average SO_2 concentration above 1,300 micrograms per cubic meter, the results of the model calculations indicate that the Port Angeles area is an attainment area for the 3-hour NAAQS.

1-Hour Concentrations

The State of Washington has a 1-hour SO_2 ambient air quality standard of 0.40 parts per million (ppm), which corresponds to 1,048 micrograms per cubic meter in metric units. This standard is exceeded at a given point during the second hour in a year with a 1-hour concentration above 1,048 micrograms per cubic meter. Although compliance with the 1-hour standard does not affect the attainment status of the Port Angeles area for the NAAQS, we also assessed the compliance of the existing sources with the Washington 1-hour standard. The maximum 1-hour concentration calculated for emissions from the ITT Rayonier Mill alone of 2,234 micrograms per cubic meter occurs during the third hour of 3-hour Case 34 at the same point as the calculated maximum 3-hour concentration. Because the 1-hour concentration calculated at this point exceeds 1,048 micrograms per cubic meter during each hour of the 3-hour period, our results indicate that the 1-hour Washington standard is violated by the stack emissions from the ITT Mill. The maximum 1-hour concentration calculated for emissions from the Crown Zellerbach Mill alone of 592 micrograms per cubic meter (first hour of 3-hour Case 17) is well below the 1-hour standard. Thus, the results of the model calculations show that emissions from the Crown Zellerbach Mill alone do not endanger the 1-hour standard. The contributions of the individual sources to the maximum 1-hour SO_2 concentrations calculated for the ITT Rayonier and Crown Zellerbach Mills are listed in Table 4-13.

4.2 THE PSD INCREMENT ANALYSIS FOR THE PROPOSED SOURCES

4.2.1 Annual Average Ground-Level SO_2 Concentrations

We used the "worst-case" source inputs given in Section 2.1 for the proposed Northern Tier Pipeline Company (NTPC) sources (tankers) with the long-term concentration modeling techniques described in Section 4.1.1 to calculate seasonal and annual average ground-level SO_2 concentrations attributable to emissions from the NTPC sources. The results of these calculations were also merged with the seasonal and annual average SO_2 concentrations calculated for the existing sources in Section 4.1.1 to assess compliance with the annual National Ambient Air Quality Standard (NAAQS) for SO_2.

Figure 4-6 shows the calculated isopleths of annual average ground-level SO_2 concentration attributable to emissions from the proposed NTPC sources. As shown by the figure, the maximum annual impact for the proposed sources is calculated to occur over water in and east of Port Angeles Harbor. The maximum annual average SO_2 concentration calculated for emissions from the NTPC sources alone is 9.74 micrograms per cubic meter, or about 49 percent of the annual Class II Prevention of Significant Deterioration (PSD) Increment for SO_2 of 20 micrograms per cubic meter. Table 4-14 gives the contributions of the individual NTPC sources to this calculated maximum concentration.

As discussed in Section 1.2, Olympic National Park is a mandatory Federal Class I (pristine air quality) area. The maximum annual average SO_2 concentration calculated at Olympic National Park for the "worst-case" emissions from the proposed NTPC sources is 0.79 micrograms

TABLE 4-13

CONTRIBUTIONS OF THE INDIVIDUAL SOURCES TO THE MAXIMUM 1-HOUR SO_2 CONCENTRATIONS CALCULATED FOR THE ITT RAYONIER MILL AND CROWN ZELLERBACH MILL

Source	Concentration ($\mu g/m^3$)
(a) ITT Rayonier Mill*	
Recovery Furnace	4
West and East Vents (Acid Plant)	734
North Bleach Vent	14
South Bleach Vent	50
Power Boiler No. 4	877
Power Boiler No. 5	537
H.F. Boiler No. 5	18
ITT Rayonier Total	2,234
(b) Crown Zellerbach Mill**	
H.F. Boiler No. 8	470
Package Boiler	122
Crown Zellerbach Total	592

*The location of the maximum 1-hour concentration calculated for the ITT Mill is the same as the location of the maximum 3-hour concentration calculated for the mill (see Case 34 in Table 4-10).

**The receptor with the maximum 1-hour concentration calculated for the Crown Zellerbach Mill is located 0.6 kilometers from the stacks at an azimuth bearing of 230 degrees. The receptor elevation is 35 meters MSL.

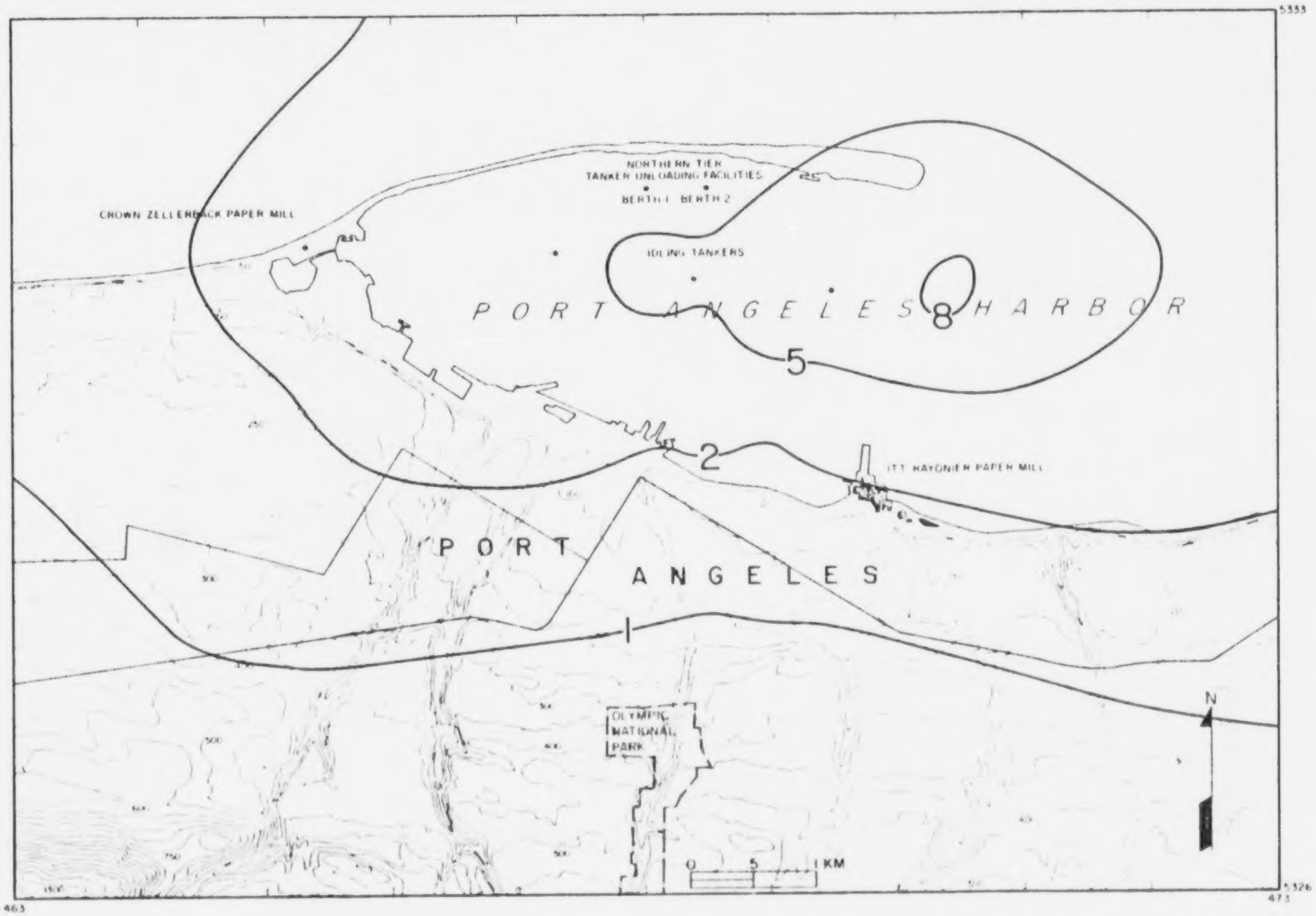


FIGURE 4-6. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the proposed NTPC sources.

TABLE 4-14

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM ANNUAL AVERAGE SO_2 CONCENTRATION CALCULATED FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES ALONE

Source	Concentration* ($\mu g/m^3$)
Tanker Unloading at West Berth	1.34
Tanker Unloading at East Berth	1.55
Tanker Idling (West Harbor)	1.26
Tanker Idling (Center Harbor)	2.22
Tanker Idling (East Harbor)	3.37
NTPC Total	9.74

*The UTM X and Y coordinates of the calculated maximum concentration are 470.5 and 5,331.0 kilometers, respectively. The receptor elevation is 0 meters MSL.

TABLE 4-15

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM ANNUAL AVERAGE SO_2 CONCENTRATION CALCULATED AT THE OLYMPIC NATIONAL PARK VISITOR CENTER FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

Source	Concentration* ($\mu g/m^3$)
Tanker Unloading at West Berth	0.13
Tanker Unloading at East Berth	0.14
Tanker Idling (West Harbor)	0.16
Tanker Idling (Center Harbor)	0.17
Tanker Idling (East Harbor)	0.19
Total for NTPC Sources	0.79

*The UTM X and Y coordinates of the calculated maximum concentration are 467.7 and 5,327.5 kilometers, respectively. The receptor elevation is 94 meters MSL.

per cubic meter, or about 40 percent of the annual Class I PSD Increment of 2 micrograms per cubic meter. The Universal Transverse Mercator (UTM) X and Y coordinates of this receptor are 467.7 and 5,327.5 kilometers, respectively. The receptor elevation is 94 meters above mean sea level (MSL). The contributions of the individual NTPC sources to the maximum annual average SO_2 concentration calculated at the Visitor Center are given in Table 4-15.

Figure 4-7 shows the calculated isopleths of annual average ground-level SO_2 concentration attributable to the combined emissions from the existing and proposed sources in the Port Angeles area. The location of the maximum annual concentration calculated for the combined emissions from the existing and proposed sources is identical to the location of the maximum annual concentration calculated for emissions from the existing sources alone. Table 4-16 gives the contributions of the existing and proposed sources to the calculated maximum annual concentration. As shown by the table, emissions from the ITT Rayonier Mill account for about 94 percent of the calculated maximum concentration of 34.1 micrograms per cubic meter. If the annual background is assumed to be 13 micrograms per cubic meter (see Section 4.1.1), the resulting maximum annual concentration is 47.1 micrograms per cubic meter, or about 59 percent of the annual NAAQS of 80 micrograms per cubic meter.

4.2.2 Maximum Short-Term Ground-Level SO_2 Concentrations

24-Hour Average Concentrations

Section 4.1.2 identifies 18 calendar days with meteorological conditions conducive to high 24-hour average ground-level SO_2 concentrations as a result of emissions from the existing SO_2 sources in the Port Angeles area. These meteorological conditions are also likely to maximize the 24-hour average ground-level concentrations produced by emissions from the proposed NTPC SO_2 sources. Consequently, we repeated the 24-

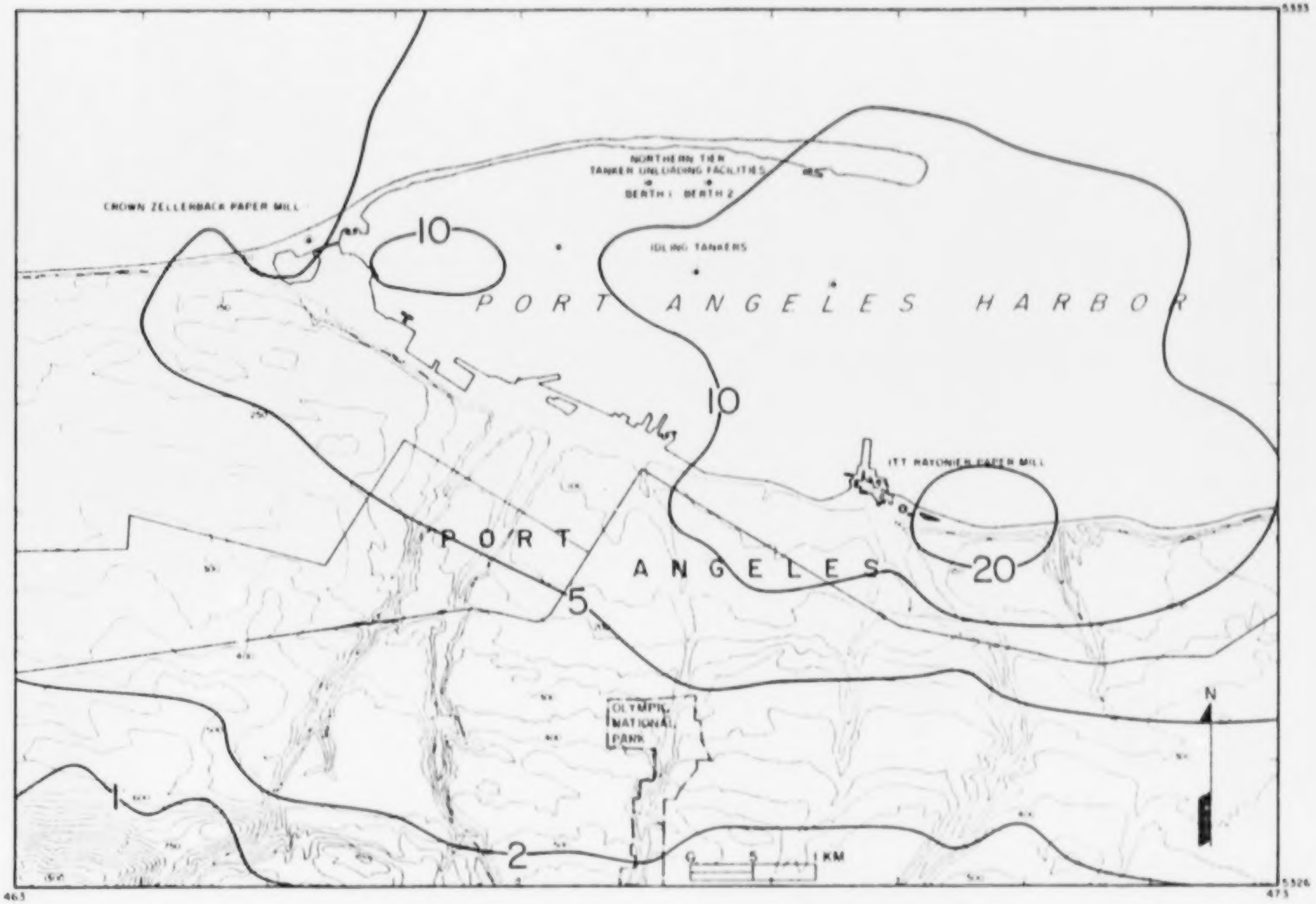


FIGURE 4-7. Calculated isopleths of annual average ground-level SO_2 concentration in micrograms per cubic meter attributable to the combined emissions from the existing Crown Zellerbach and ITT Rayonier Mills and the proposed NTPC sources.

TABLE 4-16

CONTRIBUTIONS OF THE EXISTING AND PROPOSED SOURCES TO THE MAXIMUM ANNUAL AVERAGE GROUND-LEVEL SO_2 CONCENTRATION CALCULATED IN THE PORT ANGELES AREA

Source	Concentration* ($\mu g/m^3$)
ITT Rayonier Mill (existing)	31.99
Crown Zellerbach Mill (existing)	0.48
NTPC Sources (proposed)	1.62
Total for Existing and Proposed Sources	34.10
Background	13.00
Maximum Annual Concentration	47.10

*The UTM X and Y coordinates of the calculated maximum concentration are 470.30 and 5,328.74 kilometers, respectively. The receptor elevation is 40 meters MSL.

hour average concentration calculations for these days using the "worst-case" emissions data given in Section 2.1 for the proposed NTPC sources. Additionally, we used our PRSIST data analysis program to isolate three 24-hour periods with relatively high occurrence frequencies of the north-northwest to north-northeast winds required to transport emissions from the NTPC sources to the nearest boundary of Olympic National Park, the Visitor Center. The hourly meteorological inputs for the three "worst-case" days for the Visitor Center are listed in Appendix B.

With the exception of the receptor grid, the procedures used to calculate maximum 24-hour average SO_2 concentrations for the proposed NTPC sources were identical to those outlined in Section 4.1.2. Approximately 50 percent of the "worst-case" NTPC emissions are from three idling tankers spaced at 1.1-kilometer intervals and approximately 50 percent of the emissions are from two unloading tankers with a 0.5-kilometer separation (see Figure 1-1). We considered both Cartesian and polar receptor grid systems for use in the short-term concentration calculations and plotted examples of both systems on maps showing the locations of the five NTPC sources. On the basis of these maps, we concluded that the use of a receptor array in polar coordinates was the most efficient means of detecting maximum short-term concentrations attributable to the tanker emissions. The origin of the array was placed between the two unloading tankers and receptors were placed at radial distances of 0.5, 0.7, 0.9, 1.1, 1.3, 1.5, 1.7, 2.0, 2.2, 2.5, 2.7, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0 and 7.0 kilometers. The angular spacing between receptors was 5 degrees. This grid system results in a dense spacing of receptors in the areas of expected maximum short-term air quality impacts for each of the five NTPC sources. Additionally, discrete receptors were spaced at 100-meter intervals around the nearest boundary of Olympic National Park.

Table 4-17 summarizes the results of the 24-hour average ground-level SO_2 concentration calculations for the proposed NTPC sources

TABLE 4-17

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

24-Hour Case No.	Date	Concentration ($\mu g/m^3$)	Locations*		
			Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	21 Aug 78	52	2.0	120	0
2	10 Nov 78	40	1.7	235	0
3	24 Mar 79	45	2.0	120	0
4	6 Apr 79	50	2.0	115	0
5	29 Apr 79	74	2.2	115	0
6	26 May 79	42	2.0	120	0
7	3 Jun 79	75	2.0	115	0
8	8 Jun 79	35	2.0	125	0
9	10 Jun 79	62	1.1	140	0
10	26 Jun 79	69	2.0	115	0
11	28 Jun 79	69	2.2	115	0
12	19 Jul 79	48	2.0	120	0
13	21 Jul 79	62	2.0	120	0
14	22 Jul 79	48	2.0	120	0
15	24 Jul 79	53	2.0	120	0
16	25 Jul 79	66	2.0	120	0
17	2 Aug 79	45	2.0	120	0
18	8 Aug 79	63	1.1	140	0

*Locations are with respect to the point with UTM coordinates X = 468.26 kilometers, Y = 5,331.61 kilometers.

for the 18 "worst-case" days selected in Section 4.1.2. The calculated maximum 24-hour average SO_2 concentration of 75 micrograms per cubic meter (Case 7) is 82 percent of the 24-hour Class II PSD Increment of 91 micrograms per cubic meter. The highest, second-highest 24-hour concentration occurs at the same point as the maximum concentration and is 69 micrograms per cubic meter (Case 10), or 76 percent of the 24-hour Class II Increment. Figure 4-8 shows the isopleths of 24-hour average ground-level SO_2 concentration calculated for the combined emissions from the proposed NTPC sources on the "worse-case" day for Class II areas (3 June 1979). As shown by the figure, west-northwest winds align the emissions from the three idling tankers and cause the maximum 24-hour concentration for the combined emissions to occur at the point of maximum impact for the tanker idling in the east harbor. The contributions of the individual sources to the maximum 24-hour concentration calculated for the combined emissions from the NTPC sources are given in Table 4-18.

To assess the effects of emissions from the proposed NTPC sources on the attainment status of the Port Angeles area for the 24-hour NAAQS, we included the proposed NTPC sources with the existing sources and repeated the 24-hour average SO_2 concentration calculations described in Section 4.1.2. Table 4-19 gives the magnitudes and locations of the maximum 24-hour average ground-level SO_2 concentrations calculated for the combined emissions from the existing and proposed sources. For each of the 18 "worst-case" days, emissions from the ITT Rayonier Mill are primarily responsible for the calculated maximum 24-hour concentration. As discussed in Section 4.1.2, emissions from the existing sources alone result in five days with calculated 24-hour concentrations above the 24-hour NAAQS, leading to the calculated non-attainment area(s) for the 24-hour NAAQS shown in Figures 4-3 (a) and 4-3 (b). EPA defines a "significant" impact of emissions from a proposed source on a non-attainment area for the 24-hour NAAQS for SO_2 as a 24-hour SO_2 concentration above 5 micrograms per cubic meter. Table 4-19 shows that the contribution of emissions from the proposed NTPC sources to the 24-hour

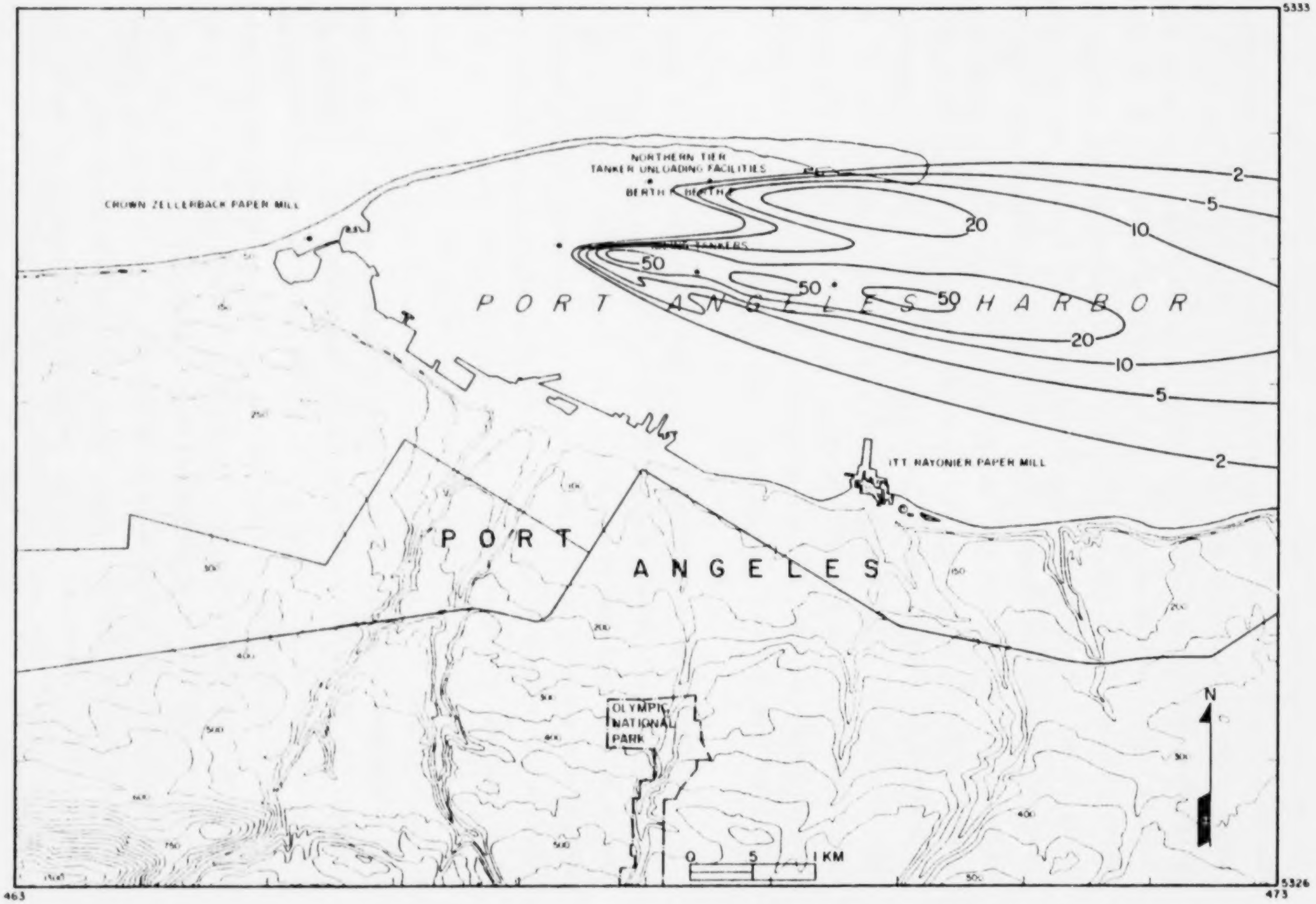


FIGURE 4-8. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the proposed NTPC sources during the "worst-case" day (3 June 1979) for emissions from the NTPC sources at Class II areas.

TABLE 4-18

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATION CALCULATED FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

Source	Concentration ($\mu g/m^3$)
Tanker Unloading at West Berth	2
Tanker Unloading at East Berth	2
Tanker Idling (West Harbor)	7
Tanker Idling (Center Harbor)	15
Tanker Idling (East Harbor)	51
Total for NTPC Sources	75

TABLE 4-19

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE COMBINED EMISSIONS FROM THE EXISTING AND PROPOSED SOURCES

24-Hour Case No.	Concentration ($\mu g/m^3$)					Location *		
	ITT	Crown Zellerbach	NTPC	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	522	18	6	13	559	1.0	115	47
2	581	12	0	13	606	0.4	220	23
3	323	6	0	13	336	0.7	120	40
4	243	4	0	13	260	0.7	120	40
5	298	1	0	13	312	0.7	100	0
6	437	6	1	13	451	0.7	120	40
7	320	1	0	13	451	0.7	100	0
8	231	3	2	26	262	0.7	125	40
9	273	3	0	13	289	0.7	100	0
10	256	2	0	13	258	0.7	095	0
11	275	0	0	13	288	0.7	100	0
12	467	6	2	29	498	0.7	120	40
13	262	5	0	13	280	1.0	115	47
14	245	3	2	13	263	0.7	125	40
15	421	4	1	13	439	0.7	120	40
16	272	4	1	13	290	0.7	120	40
17	325	4	2	13	344	0.7	120	40
18	198	1	2	13	214	0.7	130	40

*Locations are with respect to the point with UTM coordinates X = 469.74 kilometers, Y = 5,329.19 kilometers.

average concentration calculated for the combined emissions from the existing and proposed sources is 6 micrograms per cubic meter on one of the five days (Case 1). However, the simultaneous occurrence of the "worst-case" emissions scenario for the proposed NTPC sources and the meteorological conditions conducive to a "significant" impact on the non-attainment area calculated east-southeast of the ITT Mill is likely to have a low probability. Also, emissions from the proposed NTPC sources do not cause any additional calculated 24-hour concentrations above the 24-hour NAAQS and do not affect the size of the calculated non-attainment area(s).

Table 4-20 gives the magnitudes and locations of the maximum 24-hour average SO_2 concentrations calculated at the Olympic National Park Visitor Center for the combined emissions from the proposed NTPC sources on the three "worst-case" days for the Visitor Center. The calculated maximum concentration of 11.5 micrograms per cubic meter is about 2.3 times the 24-hour Class I PSD Increment of 5 micrograms per cubic meter. Also, the 24-hour Class I Increment is exceeded more than once at the same point. Thus, the results of the 24-hour concentration calculations indicate that the "worst-case" emissions from the proposed NTPC sources will violate the PSD Regulations for Class I areas at Olympic National Park. Figure 4-9 shows the calculated isopleths of 24-hour average ground-level SO_2 concentration attributable to emissions from the proposed NTPC sources on the "worst-case" day for the Olympic National Park Visitor Center (21 February 1979). The contributions of the individual NTPC sources to the maximum 24-hour concentration calculated at the Visitor Center for the combined emissions from the NTPC sources are listed in Table 4-21.

3-Hour Average Concentrations

Section 4.1.2 identifies 37 "clock-hour" 3-hour periods with meteorological conditions conducive to the occurrence of high ground-

TABLE 4-20

MAGNITUDES AND LOCATIONS OF MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED AT THE OLYMPIC NATIONAL PARK VISITOR CENTER FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

ONP 24-Hour Case No.	Date	Concentration ($\mu g/m^3$)	Location		
			UTM X (km)	UTM Y (km)	Elevation (m MSL)
1	27 Dec 78	5.8	468.4	5,327.5	84
2	10 Jan 79	6.4	468.4	5,327.5	84
3	21 Feb 79	11.5	467.7	5,327.5	94

TABLE 4-21

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM 24-HOUR AVERAGE SO_2 CONCENTRATION CALCULATED AT THE OLYMPIC NATIONAL PARK VISITOR CENTER FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

Source	Concentration ($\mu g/m^3$)
Tanker Unloading at West Berth	1.5
Tanker Unloading at East Berth	5.2
Tanker Idling (West Harbor)	0.0
Tanker Idling (Center Harbor)	4.6
Tanker Idling (East Harbor)	0.3
Total for NTPC Sources	11.5

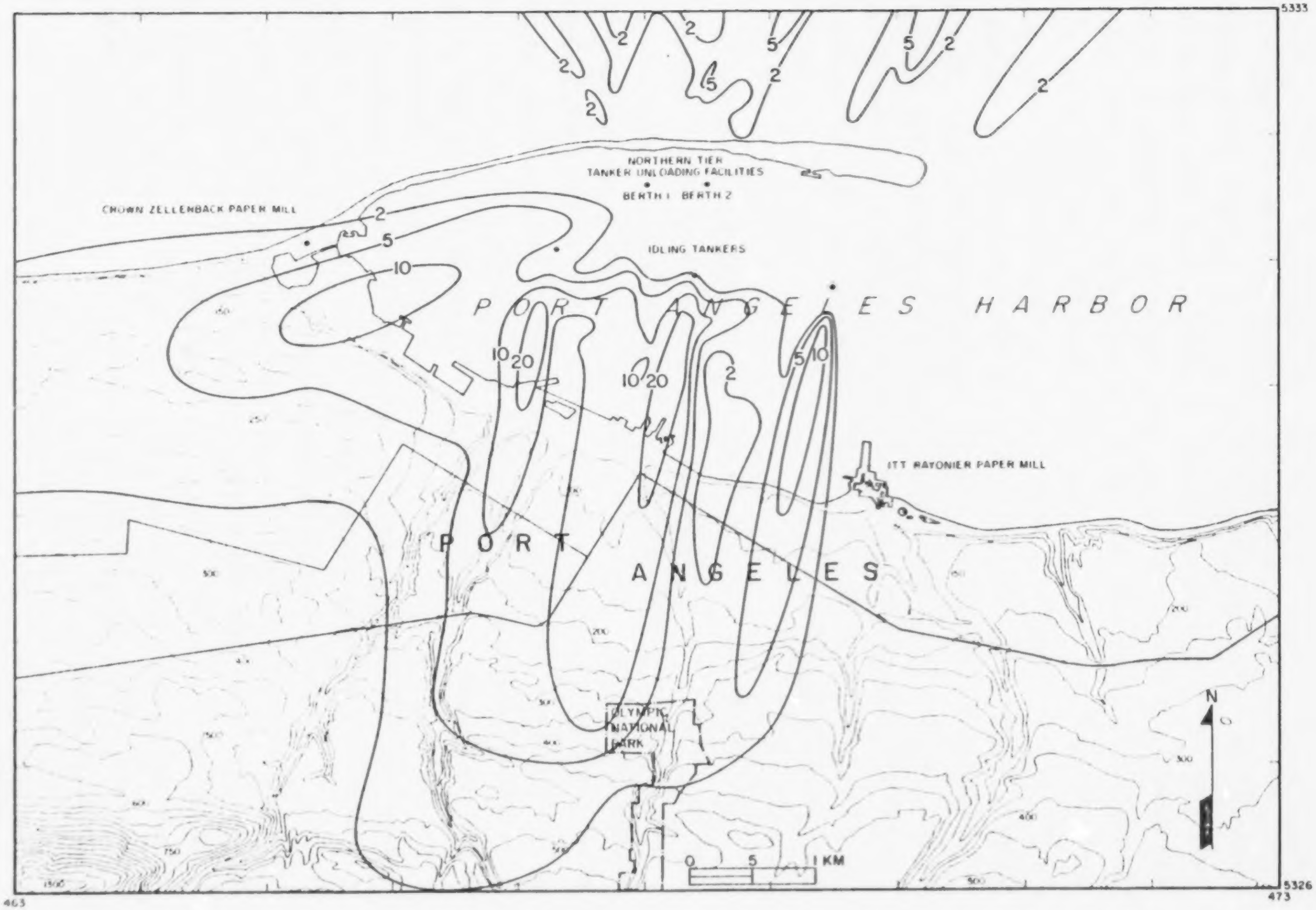


FIGURE 4-9. Calculated isopleths of 24-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the proposed NTPC sources during the "worst-case" day (21 February 1979) for emissions from the NTPC sources at Class I areas.

level concentrations as a result of stack emissions from either the existing sources or the proposed NTPC sources. We used the "worst-case" emissions data given in Section 2.1 for the proposed NTPC sources with the modeling techniques described above under the discussion of 24-hour average concentrations to calculate the maximum 3-hour ground-level SO_2 concentration attributable to emissions from the NTPC sources for each of the 37 3-hour periods. Additionally, we used our PRSIST data analysis program to identify eight 3-hour ("clock hour") periods with minimal wind-direction variation and wind directions within the narrow angular sector required to transport emissions from the proposed NTPC sources to the Olympic National Park Visitor Center. The hourly meteorological inputs for the eight "worst-case" 3-hour periods for the Visitor Center are listed in Appendix B.

Table 4-22 summarizes the results of the 3-hour average ground-level SO_2 concentration calculations for the proposed NTPC sources for the 37 "worst-case" 3-hour periods selected in Section 4.1.2. The calculated maximum 3-hour concentration of 222 micrograms per cubic meter (Case 22) is about 43 percent of the 3-hour Class II PSD Increment of 512 micrograms per cubic meter. The highest, second-highest 3-hour concentration occurs at the same point as the maximum concentration and is 126 micrograms per cubic meter (Case 35), or about 25 percent of the 3-hour Class II Increment. Figure 4-10 shows the isopleths of 3-hour average ground-level SO_2 concentration calculated for the combined emissions from the proposed NTPC sources during the "worst-case" 3-hour period for Class II areas (2200 through 2400 PST on 8 August 1979). The contributions of the individual sources to the maximum 3-hour concentration calculated for the combined emissions from the NTPC sources are listed in Table 4-23. As shown by Figure 4-10 and Table 4-23, the plumes from the two unloading tankers are calculated to stabilize above the top of the surface mixing layer and do not contribute to the calculated maximum 3-hour concentration.

TABLE 4-22

MAGNITUDES AND LOCATIONS OF MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

3-Hour Case No.	Date	Hours (PST)	Concentration ($\mu g/m^3$)	Location *		
				Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	23 Aug 78	1600-1800	76	2.0	130	0
2	13 Nov 78	0100-0300	67	1.7	060	0
3	12 Dec 78	1900-2100	86	2.2	330	0
4	19 Dec 78	0100-0300	69	0.9	070	0
5	20 Dec 78	0700-0900	64	2.0	065	0
6	3 Jan 79	0100-0300	66	2.5	320	0
7	5 Jun 79	2200-2400	64	1.1	350	0
8	19 Jun 79	1600-1800	103	1.3	235	0
9	27 Jan 79	0100-0300	80	2.2	110	0
10	1 Mar 79	0100-0300	96	2.7	060	0
11	24 Mar 79	1300-1500	99	1.1	140	0
12	2 Apr 79	0400-0600	77	2.2	110	0
13	6 Apr 79	1600-1800	76	2.2	120	0
14	22 Apr 79	1000-1200	60	1.5	265	0
15	29 Apr 79	0400-0600	77	3.0	105	0
16	1 May 79	0700-0900	90	2.2	115	0
17	7 May 79	1000-1200	72	1.7	235	0
18	3 Jun 79	1900-2100	150	2.0	115	0
19	10 Jun 79	0400-0600	126	2.2	115	0
20	10 Jun 79	1600-1800	91	2.2	115	0
21	10 Jun 79	2200-2400	129	2.0	115	0
22	18 Jun 79	0400-0600	75	2.2	110	0
23	20 Jun 79	0400-0600	60	1.7	065	0
24	22 Jun 79	1000-1200	66	1.3	135	0
25	26 Jun 79	1600-1800	102	2.0	115	0
26	26 Jun 79	1900-2100	107	2.0	115	0
27	28 Jun 79	1000-1200	120	2.2	115	0
28	28 Jun 79	1900-2100	108	2.0	115	0
29	29 Jun 79	0700-0900	65	1.7	080	0
30	29 Jun 79	1000-1200	72	2.7	105	0
31	8 Jul 79	1600-1800	67	1.7	070	0
32	19 Jul 79	0100-0300	125	2.0	115	0
33	21 Jul 79	0100-0300	107	2.2	115	0
34	2 Aug 79	1300-1500	97	1.1	150	0
35	2 Aug 79	2200-2400	126	2.2	115	0
36	8 Aug 79	1000-1200	86	2.0	125	0
37	8 Aug 79	2200-2400	222	2.2	115	0

*Locations are with respect to the point with UTM coordinates X = 468.26 kilometers, Y = 5,331.61 kilometers.

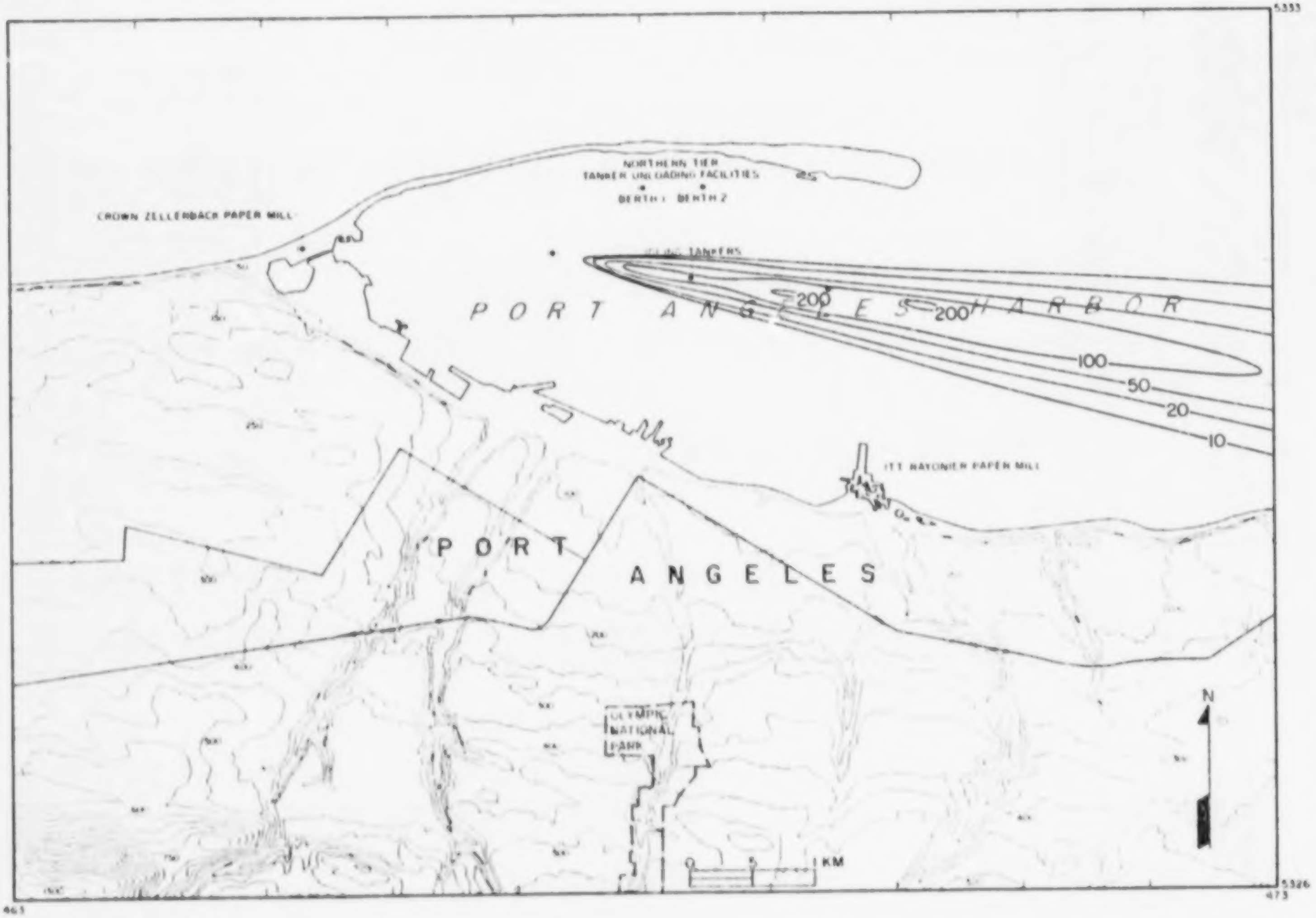


FIGURE 4-10. Calculated isopleths of 3-hour average SO_2 concentration in micrograms per cubic meter attributable to emissions from the proposed NTPC sources during the "worst-case" 3-hour period (2200 through 2400 PST on 8 August 1979) for emissions from the NTPC sources at Class II areas.

TABLE 4-23

CONTRIBUTIONS OF THE INDIVIDUAL NTPC SOURCES TO THE MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATION CALCULATED FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

Source	Concentration ($\mu g/m^3$)
Tanker Unloading at West Berth	0
Tanker Unloading at East Berth	0
Tanker Idling (West Harbor)	43
Tanker Idling (Center Harbor)	51
Tanker Idling (East Harbor)	129
Total for NTPC Sources	222

To assess compliance with the 3-hour NAAQS, we included the proposed NTPC sources with the existing sources and repeated the 3-hour average SO_2 concentration calculations described in Section 4.1.2. Table 4-24 gives the magnitudes and locations of the maximum 3-hour average ground-level SO_2 concentrations calculated for the combined emissions from the existing and proposed sources. For each of the 37 "worst-case" 3-hour periods, emissions from the ITT Rayonier Mill are principally responsible for the calculated maximum 3-hour concentration. Emissions from the proposed NTPC sources contribute an additional 1 microgram per cubic meter at the point of maximum impact of emissions from the existing sources during the single 3-hour period with a calculated 3-hour concentration above the 3-hour NAAQS (Case 34). EPA defines a "significant" impact on a non-attainment area for the 3-hour NAAQS for SO_2 as a 3-hour SO_2 concentration above 25 micrograms per cubic meter. Thus, if a single calculated 3-hour concentration above the 3-hour NAAQS is interpreted as a violation of the 3-hour NAAQS, emissions from the proposed NTPC sources are not calculated to have a "significant" impact on the 3-hour non-attainment area. Additionally, emissions from the proposed NTPC sources in combination with emissions from the existing sources do not result in any additional calculated 3-hour concentrations above the 3-hour NAAQS.

Table 4-25 gives the magnitudes and locations of the maximum 3-hour average SO_2 concentrations calculated at the Olympic National Park Visitor Center for the combined emissions from the proposed NTPC sources during the eight "worst-case" 3-hour periods for the Visitor Center. The calculated maximum 3-hour concentration of 71 micrograms per cubic meter (Case 1) is 2.84 times the 3-hour Class I PSD Increment of 25 micrograms per cubic meter. Additionally, the 3-hour Class I Increment is exceeded more than once at this point. Thus, the results of the 3-hour concentration calculations indicate that the "worst-case" emissions from the proposed NTPC sources will violate the PSD Regulations for Class I areas at Olympic National Park.

TABLE 4-24

MAGNITUDES AND LOCATIONS OF THE MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED FOR THE COMBINED EMISSIONS FROM THE EXISTING AND PROPOSED SOURCES

3-Hour Case No.	Concentration ($\mu g/m^3$)					Location *		
	ITT	Crown Zellerbach	NTPC	Background	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	1,156	33	0	13	1,202	1.2	110	46
2	540	0	0	13	553	2.0	040	0
3	460	0	0	13	473	1.5	335	0
4	496	0	0	13	509	1.5	035	0
5	400	0	0	13	413	1.2	065	0
6	460	0	0	13	473	2.0	345	0
7	494	0	0	13	507	2.0	350	0
8	584	0	0	13	597	0.8	270	16
9	434	0	0	13	447	1.2	090	0
10	528	0	0	13	541	1.5	060	0
11	564	1	0	13	577	0.7	105	0
12	441	0	0	13	454	1.2	090	0
13	853	12	0	13	878	0.9	115	37
14	463	0	0	13	476	0.4	305	0
15	512	0	0	13	525	1.2	090	0
16	515	0	0	13	528	2.0	100	46
17	694	0	0	170	864	0.4	230	22
18	659	0	0	13	672	0.7	095	0
19	606	0	0	13	619	0.8	100	0
20	539	0	0	13	552	0.7	100	0
21	588	0	0	13	601	0.7	095	0
22	456	0	0	13	469	1.2	090	0
23	452	0	0	13	465	1.0	065	0
24	460	3	0	13	476	1.5	105	35
25	511	0	0	13	524	0.7	095	0
26	523	0	0	13	536	0.7	095	0
27	567	0	0	13	580	0.8	100	0
28	529	0	0	13	542	0.7	095	0
29	456	0	0	13	469	1.2	080	0
30	475	0	0	13	488	1.2	085	0
31	657	0	0	13	670	0.5	070	0
32	533	0	0	13	546	0.8	095	0
33	604	0	0	13	617	0.7	100	0
34	1,424	5	1	13	1,443	0.7	120	40
35	559	0	0	13	572	0.9	100	0
36	1,010	1	7	13	1,031	0.6	130	38
37	406	0	0	13	419	0.8	100	0

*Locations are with respect to the point with UTM coordinates X = 469.74 kilometers, Y = 5,329.19 kilometers.

TABLE 4-25

MAGNITUDES AND LOCATIONS OF MAXIMUM 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED AT THE OLYMPIC NATIONAL PARK VISITOR CENTER FOR THE COMBINED EMISSIONS FROM THE PROPOSED NTPC SOURCES

ONP 3-Hour Case No.	Date	Hours (PST)	Concentration ($\mu g/m^3$)	Location		
				UTM X (km)	UTM Y (km)	Elevation (m MSL)
1	9 Nov 78	0700-0900	71	467.8	5,327.5	94
2	27 Dec 78	0700-0900	13	467.8	5,327.5	94
3	29 Dec 78	1000-1200	27	468.1	5,327.5	88
4	15 Jan 79	1000-1200	25	468.3	5,327.5	76
5	25 Jan 79	0700-0900	14	467.8	5,327.5	94
6	27 Jan 79	1300-1500	17	467.7	5,327.5	94
7	21 Feb 79	0400-0600	46	467.8	5,327.5	94
8	12 Apr 79	1600-1800	30	468.4	5,327.5	84

Figure 4-11 shows the calculated isopleths of 3-hour average ground-level SO_2 concentration attributable to emissions from the proposed NTPC sources during the "worst-case" 3-hour period for the Olympic National Park Visitor Center (0700 through 0900 PST on 9 November 1978). As shown by the figure, the tanker idling in the center of Port Angeles Harbor is entirely responsible for the maximum 3-hour concentration calculated for the Visitor Center. The plumes from the two tankers at the unloading berth are calculated to stabilize above the top of the surface mixing layer and do not affect the concentrations calculated at the Visitor Center during the "worst-case" 3-hour period.

4.2.3 Probability of Violating the Short-Term Class I Increments at Olympic National Park

The results of the model calculations described in Section 4.2.2 indicate that, if the "worst-case" emissions scenario for the proposed NTPC sources is assumed to exist throughout the year, emissions from the NTPC sources will violate the 3-hour and 24-hour Class I PSD Increments for SO_2 at the Olympic National Park Visitor Center. However, SO_2 emissions from the NTPC sources will not be constant throughout the year, and the periods of "worst-case" emissions will not necessarily coincide with the periods of "worst-case" meteorological conditions. Consequently, we used the statistical procedures described below to estimate the probability that the short-term Class I Increments will be violated as a result of emissions from the proposed NTPC sources.

Table 4-26 lists the source inputs used to calculate, for each hour during the period 15 August 1978 to 15 August 1979, the hourly SO_2 concentration at the Olympic National Park Visitor Center attributable to emissions from the proposed NTPC sources. The inputs in Table 4-26, which were developed from information provided by EPA Region 10 (Wilson, 1980b), assume that a single tanker with a constant stack height, stack exit temperature and volumetric emission rate is located between the two unloading berths shown in Figure 1-1. The assumption of a single source

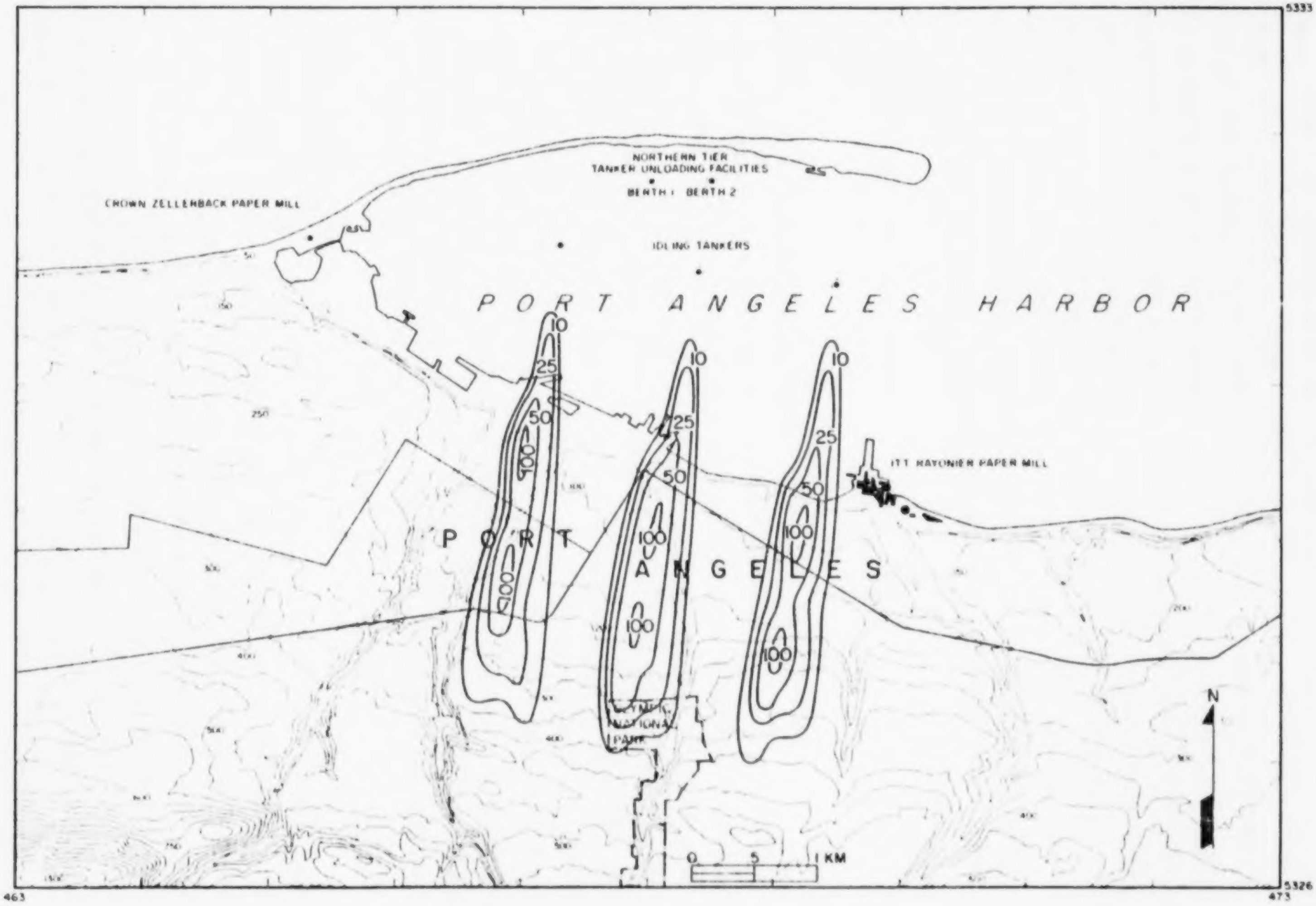


FIGURE 4-11. Calculated isopleths of 3-hour average ground-level SO_2 concentration in micrograms per cubic meter attributable to emissions from the proposed NTPC sources during the "worst-case" 3-hour period (0700 through 0900 PST on 9 November 1978) for emissions from the NTPC sources at Class I areas.

TABLE 4-26

NTPC SOURCE INPUTS FOR THE HOURLY SO_2 CONCENTRATION CALCULATIONS AT THE OLYMPIC NATIONAL PARK VISITOR CENTER

Parameter	Parameter Value
Total SO_2 Emission Rate (g/sec)	23.36
UTM X Coordinate (m)	468,260
UTM Y Coordinate (m)	5,331,610
Stack Base Elevation (m MSL)	0
Stack Height (m)	37.0
Stack Exit Temperature (^{o}K)	422
Stack Radius (m)	0.76
Volumetric Emission Rate (m^3/sec)	28.00

with constant stack height and stack exit parameters is required to apply the statistical techniques described below. The total SO_2 emissions from all NTPC sources, including unloading and idling tankers and tugboats, are included in the total SO_2 emissions from the single tanker. (We point out that the model assumption that SO_2 emissions from all NTPC sources originate from a single point biases the results of the concentration calculations toward overestimation.) The 1-hour concentrations were calculated for the receptor at the Visitor Center with the highest annual average concentration previously calculated for the combined emissions from the two unloading tankers (see Section 4.2.1). The UTM X and Y coordinates of this receptor are 467.7 and 5,327.5 kilometers, respectively. The receptor elevation is 94 meters MSL. The results of the hourly concentration calculations were used to form the cumulative frequency distributions of 3-hour and 24-hour average SO_2 concentrations shown in Tables 4-27 and 4-28, respectively.

We emphasize that the calculated 3-hour and 24-hour average SO_2 concentration distributions in Tables 4-27 and 4-28 are based on a different emissions scenario for the proposed NTPC sources than the calculated 3-hour and 24-hour average concentrations discussed in Section 4.2.2. Tables 4-27 and 4-28 assume that there are two tankers at the unloading berths with a constant combined SO_2 emission rate of 23.36 grams per second; these tankers are represented for modeling purposes by a single tanker. Section 4.2.2 assumes two unloading tankers and three idling tankers with a constant combined emission rate of 45.5 grams per second. Additionally, the stack heights and stack exit parameters for the unloading tankers considered in this section do not exactly correspond to the stack heights and exit parameters for either the unloading tankers or the idling tankers considered in Section 4.2.2.

In order to calculate the probability of violating the short-term Class I PSD Increments at the Olympic National Park Visitor Center,

TABLE 4-27

CUMULATIVE FREQUENCY DISTRIBUTION OF 3-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED AT THE VISITOR CENTER FOR THE REFERENCE EMISSION RATE

Concentration* ($\mu g/m^3$)	Cumulative Frequency	Total Occurrences
.00000	.946575	2764.00
.50000	.978082	2856.00
1.00000	.980137	2862.00
1.50000	.981849	2867.00
2.00000	.982534	2869.00
2.50000	.982677	2870.00
3.00000	.983904	2873.00
3.50000	.985616	2878.00
4.00000	.987329	2883.00
4.50000	.988014	2885.00
5.00000	.988356	2886.00
5.50000	.988356	2886.00
6.00000	.989041	2888.00
6.50000	.990068	2891.00
7.00000	.990411	2892.00
7.50000	.990411	2892.00
8.00000	.990753	2893.00
8.50000	.991096	2894.00
9.00000	.991438	2895.00
9.50000	.991438	2895.00
10.00000	.991781	2896.00
15.00000	.994178	2903.00
20.00000	.996575	2910.00
25.00000	.998288	2915.00
30.00000	.998973	2917.00
35.00000	.999315	2918.00
40.00000	.999315	2918.00
45.00000	.999315	2918.00
50.00000	.999658	2919.00
55.00000	.999658	2919.00
60.00000	.999658	2919.00
65.00000	.999658	2919.00
70.00000	.999658	2919.00
75.00000	.999658	2919.00
80.00000	.999658	2919.00
85.00000	.999658	2919.00
90.00000	.999658	2919.00
95.00000	1.000000	2920.00
100.00000	1.000000	2920.00
150.00000	1.000000	2920.00

*Calculated concentrations are less than or equal to the indicated values for the indicated fractions of the time. The reference (total) SO_2 emission rate is 23.36 grams per second.

TABLE 4-28

CUMULATIVE FREQUENCY DISTRIBUTION OF 24-HOUR AVERAGE SO_2 CONCENTRATIONS CALCULATED AT THE VISITOR CENTER FOR THE REFERENCE EMISSION RATE

Concentration* ($\mu g/m^3$)	Cumulative Frequency	Total Occurrences
.00000	.717808	262.00
.50000	.917808	335.00
1.00000	.936986	342.00
1.50000	.947945	346.00
2.00000	.956164	349.00
2.50000	.967123	353.00
3.00000	.969863	354.00
3.50000	.978082	357.00
4.00000	.986301	360.00
4.50000	.991781	362.00
5.00000	.991781	362.00
5.50000	.991781	362.00
6.00000	.991781	362.00
6.50000	.994521	363.00
7.00000	.997260	364.00
7.50000	.997260	364.00
8.00000	.997260	364.00
8.50000	.997260	364.00
9.00000	.997260	364.00
9.50000	.997260	364.00
10.00000	.997260	364.00
15.00000	1.000000	365.00
20.00000	1.000000	365.00
25.00000	1.000000	365.00

*Calculated concentrations are less than or equal to the indicated values for the indicated fractions of the time. The reference (total) SO_2 emission rate is 23.36 grams per second.

we define χ_i as the upper bound of the i^{th} 3-hour or 24-hour concentration interval in Table 4-27 or 4-28. The 3-hour and 24-hour total SO_2 emissions frequency distributions for the proposed NTPC sources are listed in Tables 4-29 and 4-30, respectively. (Tables 4-29 and 4-30 were developed from information provided by Wilson, 1980b.) We define Q_j as the mean 3-hour or 24-hour total SO_2 emission rate for the j^{th} emissions interval in Table 4-29 or 4-30. Finally, for a constant total SO_2 emission rate Q_o (in this case, 23.36 grams per second), we define $F\{\chi_i\}$ as the cumulative frequency of occurrence of calculated concentrations less than or equal to χ_i (see Tables 4-27 and 4-28).

The cumulative frequency of occurrence of calculated concentrations less than or equal to the concentration χ' for a variable emissions distribution is given by

$$F\{\chi'\} = \sum_{j=1}^{M} \left(f_j \; F_j\{\chi'\} \right) \qquad (4\text{-}1)$$

where f_j is the frequency of occurrence of the emission rate Q_j and $F_j\{\chi'\}$ is the frequency of occurrence of calculated concentrations less than or equal to χ' for a constant total emission rate Q_j. The frequency $F_j\{\chi'\}$ is interpolated from the expressions

$$F_j\{\chi'\} = F\{\chi_{j,i}\} + \left(F\{\chi_{j,i+1}\} - F\{\chi_{j,i}\} \right) \left(\frac{\chi' - \chi_{j,i}}{\chi_{j,i+1} - \chi_{j,i}} \right) \qquad (4\text{-}2)$$

$$\chi_{j,i} = \frac{Q_j}{Q_o} \chi_i \qquad (4\text{-}3)$$

TABLE 4-29

FREQUENCY DISTRIBUTION OF NTPC 3-HOUR SO_2 EMISSIONS

Category Number	Range of SO_2 Emissions* (g/sec)	Mean SO_2 Emission Rate* (g/sec)	Percent Frequency of Occurrence
1	0.0000-1.1718	0.5859	32.9
2	1.1718-2.3310	1.7514	5.8
3	2.3310-3.5028	2.9169	2.8
4	3.5028-4.6746	4.0887	3.2
5	4.6746-5.8464	5.2605	2.8
6	5.8464-7.0056	6.4260	8.4
7	7.0056-8.1774	7.5915	10.6
8	8.1774-9.3492	8.7633	7.0
9	9.3492-10.5084	9.9288	8.2
10	10.5084-11.6802	11.0943	4.0
11	11.6802-12.8520	12.2661	2.3
12	12.8520-14.0238	13.4379	2.7
13	14.0238-15.1830	14.6034	2.0
14	15.1830-16.3548	15.7689	2.4
15	16.3548-17.5266	16.9407	2.3
16	17.5266-18.6858	18.1062	1.4
17	18.6858-19.8576	19.2717	0.5
18	19.8576-21.0294	20.4435	0.6
19	21.0294-22.2012	21.6153	0.1
20	22.2012-23.3604	22.7808	0.1

*Emissions are the total emissions from all NTPC sources.

TABLE 4-30

FREQUENCY DISTRIBUTION OF NTPC 24-HOUR SO_2 EMISSIONS

Category Number	Range of SO_2 Emissions* (g/sec)	Mean SO_2 Emission Rate (g/sec)	Percent Frequency of Occurrence
1	0.0000 - 1.0332	0.5166	13.8
2	1.0332 - 2.0790	1.5561	5.9
3	2.0790 - 3.1122	2.5956	5.3
4	3.1122 - 4.1454	3.6288	7.6
5	4.1454 - 5.1786	4.6620	9.7
6	5.1786 - 6.2244	5.7015	9.1
7	6.2244 - 7.2576	6.7410	10.0
8	7.2576 - 8.2908	7.7742	10.1
9	8.2908 - 9.3366	8.8137	9.2
10	9.3366 -10.3698	9.8532	7.0
11	10.3698 -11.4030	10.8864	4.6
12	11.4030 -12.4488	11.9259	3.2
13	12.4488 -13-4820	12.9654	1.9
14	13.4820 -14.5152	13.9986	1.2
15	14.5152 -15.5484	15.0318	0.7
16	15.5484 -16.5942	16.0713	0.3
17	16.5942 -17.6274	17.1108	0.2
18	17.6274 -18.6606	18.1440	0.1
19	18.6606 -19.7064	19.1835	0.1
20	19.7064 -20.7396	20.2230	0.0

*Emissions are the total emissions from all NTPC sources.

where the concentration χ' in Equation (4-2) is contained in the interval defined by the concentrations $\chi_{j,i}$ and $\chi_{j,i+1}$.

The composite cumulative frequency distribution of 3-hour concentrations at the Visitor Center attributable to emissions from the proposed NTPC sources is given in Table 4-31. This table was calculated using Equations (4-1) through (4-3) with the 3-hour concentration frequency distribution for constant total emissions given in Table 4-27 and the 3-hour emissions distribution given in Table 4-29. Similarly, the composite cumulative frequency distribution of 24-hour SO_2 concentrations at the Visitor Center, based on Tables 4-28 and 4-30, is shown in Table 4-32.

The probability of one or more occurences during a year of a short-term concentration above the corresponding short-term Class I PSD Increment is

$$P\{V\} = 1.0 - P\{0\} \qquad (4\text{-}4)$$

where P{0} is the probability of exactly zero occurrences. Similarly, the probability of two or more occurrences during a year is

$$P\{V\} = 1.0 - P\{0\} - P\{1\} \qquad (4\text{-}5)$$

where P{1} is the probability of exactly one occurrence. Assuming the N 3-hour or 24-hour periods in a year to be independent, each with a probability p of an occurrence (success) and a probability (1-p) of a non-occurrence (failure), the binominal law gives the probability of K occurrences (successes) as

$$P\{K\} = \frac{N!}{K!\,(N-K)!}\, p^{K}\,(1-p)^{N-K} \qquad (4\text{-}6)$$

Equation (4-6) is substituted for P{0} in Equation (4-4) and for both P{0} and P{1} in Equation (4-5). Thus, if a single calculated short-term concen-

TABLE 4-31

COMPOSITE CUMULATIVE FREQUENCY DISTRIBUTION OF 3-HOUR SO_2 CONCENTRATIONS CALCULATED AT THE VISITOR CENTER FOR VARIABLE EMISSIONS FROM THE PROPOSED NTPC SOURCES

Concentration* ($\mu g/m^3$)	Composite Cumulative Frequency
0.0	0.94658
5.0	0.99615
10.0	0.99859
15.0	0.99938
20.0	0.99967
25.0	0.99977
30.0	0.99984
35.0	0.99989
40.0	0.99993

*Calculated concentrations are less than or equal to the indicated values for the individual fractions of the time.

TABLE 4-32

COMPOSITE CUMULATIVE FREQUENCY DISTRIBUTION OF 24-HOUR SO_2 CONCENTRATIONS CALCULATED AT THE VISITOR CENTER FOR VARIABLE EMISSIONS FROM THE PROPOSED NTPC SOURCES

Concentration* ($\mu g/m^3$)	Composite Cumulative Frequency
0.0	0.71781
1.0	0.98121
2.0	0.99486
3.0	0.99769
4.0	0.99893
5.0	0.99946
6.0	0.99975
7.0	0.99990
8.0	0.99996
9.0	0.99999
10.0	1.00000

*Calculated concentrations are less than or equal to the indicated values for the indicated fractions of the time.

tration above the corresponding Class I PSD Increment is interpreted as a violation of the increment, the probability of violating the 3-hour Class I Increment is

$$P\{V_3\} = 1 - (1-p_3)^{2920} \tag{4-7}$$

and the probability of violating the 24-hour Class I Increment is

$$P\{V_{24}\} = 1 - (1-p_{24})^{365} \tag{4-8}$$

Similarly, if two or more occurrences of calculated short-term concentrations above the corresponding Class I PSD Increment are required for a violation of the increment, the probabilities of violating the 3-hour and 24-hour Class I Increments are

$$P\{V_3\} = 1 - (1-p_3)^{2920} - 2920\ p_3\ (1-p_3)^{2919} \tag{4-9}$$

$$P\{V_{24}\} = 1 - (1-p_{24})^{365} - 365\ p_{24}\ (1-p_{24})^{364} \tag{4-10}$$

Table 4-31 gives the probability p_3 of a 3-hour SO_2 concentration above the 3-hour Class I PSD Increment of 25 micrograms per cubic meters as 0.00023. If a single occurrence of a calculated 3-hour concentration above the 3-hour Class I PSD Increment is defined as a violation of the increment, it follows from Equation (4-7) that the probability of violating the 3-hour Class I Increment is 0.489. Thus, if meteorological conditions are similar during ever year, the 3-hour Class I Increment might be violated once every 2.0 years. However, if two or more calculated 3-hour concentrations above the 3-hour Class I Increment are required in a year in order to violate the increment, Equation (4-9) gives the probability of violating the 3-hour Class I Increment as 0.146, or once every 6.8 years.

Table 4-32 gives the probability p_{24} of a 24-hour concentration at the Visitor Center above the 24-hour Class I PSD Increment of 5 micrograms per cubic meter as 0.00054. If a single occurrence of a 24-hour concentration above the 24-hour Class I PSD Increment is interpreted as a violation of the increment, Equation (4-8) gives the probability of violating the increment as 0.179, or once every 5.6 years. Similarly, if two or more calculated 24-hour concentrations above the 24-hour Class I Increment are required in a year in order to violate the increment, Equation (4-10) gives the probability of violating the 24-hour Class I Increment as 0.017, or about once every 58.8 years.

SECTION 5

RESULTS OF THE CONTROL STRATEGY CALCULATIONS

The results of the attainment status calculations described in Section 4.1 for the existing SO_2 sources in the Port Angeles area indicate that the 3-hour and/or 24-hour National Ambient Air Quality Standards (NAAQS) for SO_2 are violated in the Port Angeles area. If any calculated short-term concentration above the corresponding short-term NAAQS is defined as a violation of the NAAQS, the 3-hour NAAQS is calculated to be violated once per year in the area east-southeast of the ITT Rayonier Mill and the 24-hour NAAQS is calculated to be violated once per year in the area southwest of the ITT Mill and four times per year in the area east-southeast of the ITT Mill (see Figure 4-3(a) in Section 4.1.2). If it is assumed that a short-term NAAQS is violated at a given point during the second short-term period in a year with a calculated concentration above the corresponding NAAQS, the 24-hour NAAQS is calculated to be violated three times per year in the area east-southeast of the ITT Mill (See Figure 4-3(b) in Section 4.1.2). To assist in determining how best to attain the 3-hour and/or 24-hour NAAQS in the Port Angeles area, EPA Region 10 requested that we evaluate the effects on SO_2 ambient air quality of the eight emission control strategies summarized in Table 5-1 for the ITT Mill. The source inputs for the control strategies, which are based on information provided by EPA Region 10 (Wilson, 1980c), are listed in Tables 5-2 and 5-3.

For each of the five days with calculated 24-hour average concentrations above the 24-hour NAAQS and for the single 3-hour period with calculated 3-hour average concentrations above the 3-hour NAAQS, we used the short-term source inputs given in Section 2.1 for the Crown Zellerbach Mill and the control strategy source inputs for the ITT Mill with the short-term modeling techniques described in Section 4.1.2 to calculate the ground-level SO_2 concentration pattern for each control strategy. Table 5-4 gives the results of the 24-hour concentration calculations and Table 5-5 gives the results of the 3-hour concentration calculations. These results may be summarized as follows:

TABLE 5-1

DESCRIPTION OF THE EMISSION CONTROL STRATEGIES FOR THE ITT RAYONIER PULP MILL

Control Strategy Number	Control Strategy Description
1*	Duct SO_2 emissions from the West and East Vents (Acid Plant) to the Recovery Furnace Stack
2	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 250 ppm
3	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 100 ppm
4	Reduce the sulfur content of the fuel for Power Boilers No. 4 and No. 5 to 1.0%
5	Reduce the sulfur content of the fuel for Power Boilers No. 4 and No. 5 to 0.5%
6	Combine Strategies No. 2 and No. 4
7	Current Optimum ITT emissions (see Table 2-3)
8	Reduce the in-stack SO_2 concentration for the West and East Vents (Acid Plant) to 50 ppm

*This control strategy is contrary to Secton 123 of the Clean Air Act.

TABLE 5-2

ITT SOURCE INPUTS OTHER THAN SO_2 EMISSION RATES FOR THE CONTROL STRATEGIES

Source Number*	Source Coordinates		Stack Base Elevation (m MSL)	Stack Height (m)	Stack Exit Temp. (^oK)	Stack Radius (m)	24-Hour Volumetric Emission Rate (m^3/sec)
	UTM X (m)	UTM Y (m)					
001	469,790	5,329,250	3	96.0	300	1.15	50.00 (61.80)**
002	469,753	5,329,185	3	33.5	289	0.30	5.90 (0.00)**
004	469,758	5,329,184	3	35.7	303	0.75	9.90
005	469,769	5,329,183	3	35.4	296	0.61	9.20
006	469,720	5,329,194	3	35.1	480	1.22	37.80
007	469,718	5,329,183	3	35.1	480	0.84	45.80
008	469,698	5,329,165	3	45.7	336	1.22	77.40

*See Table 2-1 in Section 2.1 for the identification of the ITT sources by source number.

**The volumetric emission rates enclosed by parentheses apply to Control Strategy No. 1 only.

TABLE 5-3

SHORT-TERM SO_2 EMISSION RATES FOR THE ITT CONTROL STRATEGIES

Control Strategy Number	SO_2 Emission Rate (g/sec)						
	Source No. 1	Source No. 2	Source No. 4	Source No. 5	Source No. 6	Source No. 7	Source No. 8
1	57.1	0.0	0.4	1.4	29.0	29.0	2.8
2	41.3	7.6	0.4	1.4	29.0	29.0	2.8
3	41.3	3.0	0.4	1.4	29.0	29.0	2.8
4	41.3	15.8	0.4	1.4	19.3	19.3	2.8
5	41.3	15.8	0.4	1.4	9.7	9.7	2.8
6	41.3	7.6	0.4	1.4	19.3	19.3	2.8
7	22.0	5.0	0.4	1.4	0.0	0.0	0.0
8	41.3	1.6	0.4	1.4	29.0	29.0	2.8

TABLE 5-4

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE 24-HOUR NAAQS

Control Strategy Number	Date	Maximum 24-Hour Concentration ($\mu g/m^3$)				Location*		
		ITT	Crown Zellerbach	Back-ground	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	21 Aug 78	298	21	13	332	0.7	120.0	40
	10 Nov 78	480	12	13	505	0.4	222.5	22
	26 May 79	318	6	13	337	0.7	120.0	40
	19 Jul 79	346	6	29	381	0.7	120.0	40
	24 Jul 79	286	4	13	303	0.7	120.0	40
2	21 Aug 78	375	21	13	409	0.7	120.0	40
	10 Nov 78	551	12	13	576	0.4	222.5	22
	26 May 79	373	6	13	392	0.7	120.0	40
	19 Jul 79	402	6	29	437	0.7	120.0	40
	24 Jul 79	351	4	13	368	0.7	120.0	40
3	21 Aug 78	326	21	13	360	0.7	120.0	40
	10 Nov 78	508	12	13	533	0.4	222.5	22
	26 May 79	337	6	13	356	0.7	120.0	40
	19 Jul 79	366	6	29	401	0.7	120.0	40
	24 Jul 79	311	4	13	328	0.7	120.0	40
4	21 Aug 78	472	18	13	503	1.0	115.0	47
	10 Nov 78	473	12	13	498	0.4	222.5	22
	26 May 79	346	6	13	365	0.7	120.0	40
	19 Jul 79	376	6	29	411	0.6	122.5	30
	24 Jul 79	337	4	13	354	0.7	120.0	40
5	21 Aug 78	423	18	13	454	1.0	115.0	47
	10 Nov 78	338	13	13	364	0.4	220.0	23
	26 May 79	256	6	13	275	0.7	120.0	40
	19 Jul 79	281	6	29	316	0.6	122.5	30
	24 Jul 79	254	4	13	271	0.7	120.0	40
6	21 Aug 78	313	18	13	344	1.0	115.0	47
	10 Nov 78	397	12	13	422	0.4	222.5	22
	26 May 79	282	6	13	301	0.7	120.0	40
	19 Jul 79	303	6	29	338	0.7	120.0	40
	24 Jul 79	264	4	13	281	0.7	120.0	40

TABLE 5-4 (Continued)

Control Strategy Number	Date	Maximum 24-Hour Concentration ($\mu g/m^3$)				Location*		
		ITT	Crown Zellerbach	Back-ground	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
7	21 Aug 78	139	18	13	170	1.0	115.0	47
	10 Nov 78	75	21	13	109	0.5	220.0	27
	26 May 79	63	6	13	82	0.7	120.0	40
	19 Jul 79	70	6	29	105	0.6	122.5	30
	24 Jul 79	65	4	13	82	0.7	120.0	40
8	21 Aug 78	311	21	13	345	0.7	120.0	40
	10 Nov 78	495	12	13	520	0.4	222.5	22
	26 May 79	326	6	13	345	0.7	120.0	40
	19 Jul 79	355	6	29	390	0.7	120.0	40
	24 Jul 79	298	4	13	315	0.7	120.0	40

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* Locations are with respect to the point with UTM coordinates X= 469.74 kilometers, Y= 5,329.19 kilometers.

TABLE 5-5

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE 3-HOUR NAAQS

Control Strategy Number	Maximum 3-Hour Concentration* ($\mu g/m^3$)				Location**		
	ITT	Crown Zellerbach	Back-ground	Total	Distance (km)	Azimuth Bearing (deg)	Elevation (m MSL)
1	981	5	13	999	0.7	120.0	40
2	1,139	5	13	1,157	0.7	120.0	40
3	1,038	5	13	1,056	0.7	120.0	40
4	1,086	5	13	1,104	0.7	120.0	40
5	820	5	13	838	0.7	120.0	40
6	796	5	13	814	0.7	120.0	40
7	172	5	13	190	0.7	120.0	40
8	1,007	5	13	1,025	0.7	120.0	40

* The "worst-case" 3-hour period is 2200 through 2400 PST on 8 August 1979.

** Locations are with respect to the point with UTM coordinates X = 469.74 kilometers, Y = 5,329.19 kilometers.

- Control Strategy 7 is the only control strategy which attains the 24-hour NAAQS if all cases of calculated 24-hour average concentrations above the 24-hour NAAQS are defined as violations of the 24-hour standard

- Control Strategies 1, 3, 5, 6, 7 and 8 attain the 24-hour NAAQS if it is assumed that a given point may have one calculated 24-hour average concentration per year above the 24-hour NAAQS without violating the 24-hour standard

- All of the control strategies preclude calculated 3-hour average concentrations above the 3-hour NAAQS

We point out that Control Strategy 7 corresponds to the current optimum emissions from the ITT Mill. Thus, if the ITT Mill is able to achieve and maintain the current optimum emissions, the non-attainment problem will be eliminated (excluding the effects of emissions from the black liquor holding pond at the ITT Mill).

We also considered the effects of emissions from the proposed NTPC sources on the attainment status of the Port Angeles area for the eight emission control strategies for the ITT Mill. Assuming the "worst-case" emissions scenario described in Section 2.1 for the proposed NTPC sources, Table 5-6 gives the results of the control strategy calculations for the 24-hour NAAQS and Table 5-7 gives the results of the control strategy calculations for the 3-hour NAAQS. As shown by Table 5-6, the addition of emissions from the proposed NTPC sources causes the 24-hour NAAQS to be exceeded more than once per year at the same point for Control Strategy 3. With this exception, the addition of emissions from the proposed NTPC sources does not affect the conclusions of the control strategy evaluation for the existing sources that are given above.

TABLE 5-6

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE 24-HOUR NAAQS WITH THE EFFECTS OF EMISSIONS FROM THE PROPOSED NTPC SOURCES INCLUDED

Control Strategy Number	Date	Maximum 24-Hour Concentration* ($\mu g/m^3$)				
		ITT	Crown Zellerbach	NTPC	Background	Total
1	21 Aug 78	298	21	6	13	338
	10 Nov 78	480	12	0	13	505
	26 May 79	318	6	1	13	338
	19 Jul 79	346	6	2	29	383
	24 Jul 79	286	4	1	13	304
2	21 Aug 78	375	21	6	13	415
	10 Nov 78	551	12	0	13	576
	26 May 79	373	6	1	13	393
	19 Jul 79	402	6	2	29	439
	24 Jul 79	351	4	1	13	369
3	21 Aug 78	326	21	6	13	366
	10 Nov 78	508	12	0	13	533
	26 May 79	337	6	1	13	357
	19 Jul 79	366	6	2	29	403
	24 Jul 79	311	4	1	13	329
4	21 Aug 78	472	18	6	13	509
	10 Nov 78	473	12	0	13	498
	26 May 79	346	6	1	13	366
	19 Jul 79	376	6	2	29	413
	24 Jul 79	337	4	1	13	355
5	21 Aug 78	423	18	6	13	460
	10 Nov 78	338	13	0	13	364
	26 May 79	256	6	1	13	276
	19 Jul 79	281	6	2	29	318
	24 Jul 79	254	4	1	13	272
6	21 Aug 78	313	18	6	13	350
	10 Nov 78	397	12	0	13	422
	26 May 79	282	6	1	13	302
	19 Jul 79	303	6	2	29	340
	24 Jul 79	264	4	1	13	282

TABLE 5-6 (Continued)

Control Strategy Number	Date	Maximum 24-Hour Concentration* ($\mu g/m^3$)				
		ITT	Crown Zellerbach	NTPC	Background	Total
7	21 Aug 78	139	18	6	13	176
	10 Nov 78	75	21	0	13	109
	26 May 79	63	6	1	13	83
	19 Jul 79	70	6	2	29	107
	24 Jul 79	65	4	1	13	83
8	21 Aug 78	311	21	6	13	351
	10 Nov 78	495	12	0	13	520
	26 May 79	326	6	1	13	346
	19 Jul 79	355	6	2	29	392
	24 Jul 79	298	4	1	13	316

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* See Table 5-4 for the locations of the maximum concentrations.

TABLE 5-7

SUMMARY OF THE RESULTS OF THE CONTROL STRATEGY CALCULATIONS FOR THE 3-HOUR NAAQS WITH THE EFFECTS OF EMISSIONS FROM THE PROPOSED NTPC SOURCES INCLUDED

Control Strategy Number	Maximum 3-Hour Concentration* ($\mu g/m^3$)				
	ITT	Crown Zellerbach	NTPC	Background	Total
1	981	5	1	13	1,000
2	1,139	5	1	13	1,158
3	1,038	5	1	13	1,057
4	1,086	5	1	13	1,105
5	820	5	1	13	839
6	796	5	1	13	815
7	172	5	1	13	191
8	1,007	5	1	13	1,026

* The "worst-case" 3-hour period is 2200 through 2400 PST on 8 August 1979. See Table 5-5 for the locations of the maximum concentrations.

SECTION 6

IDENTIFICATION OF THE MAJOR AREAS OF UNCERTAINTY IN THE MODEL CALCULATIONS

The principal areas of uncertainty affecting the accuracy of the results of the dispersion model calculations described in this report are:

- The representativeness of the stack and emissions parameters given in Section 2.1 for the existing and proposed SO_2 sources
- The representativeness of the meteorological inputs used in the model calculations (see Section 2.2.3)
- The accuracy of the Cramer, et al. (1975) complex terrain dispersion model

The stack and emissions parameters given in Section 2.1 for the existing SO_2 sources (the Crown Zellerbach and ITT Rayonier Pulp Mills) and for the proposed NTPC SO_2 sources (tankers) were provided to the H. E. Cramer Company by EPA Region 10. In the absence of any other information we assume in this study that the parameters provided for the Crown Zellerbach Mill and for the proposed NTPC tankers are representative of actual operating conditions. According to EPA Region 10 (Boys, 1980), SO_2 emissions from the ITT Mill are lower than assumed in this study during periods of optimum operation and higher than assumed in this study during periods when the SO_2 emission control devices are operating at a decreased level of performance or when there are process upsets. (As noted in Section 2.1, the effects of emissions from the black liquor holding pond at the ITT Mill were not included in the model calculations.)

As discussed in Section 2.2.3, the meteorological data from a single site cannot always be expected to be representative of meteorological conditions over the entire Port Angeles area because of the complexity of the topography and meteorology. Of the hourly wind data available for 12 months, we selected the Ediz Hook 10-meter tower wind data for use in the dispersion model calculations because we consider these winds to be the most representative of the winds affecting the transport and dispersion of emissions from the existing and proposed SO_2 sources in the areas of maximum impacts. The Turner (1964) stability classification scheme in combination with the Cramer, et al. (1975) turbulent intensities corresponding to the Pasquill stability categories in rural areas previously yielded a close correspondence between concurrent calculated and observed SO_2 concentrations in a very similar modeling study (Cramer, et al., 1976). On the basis of this previous experience, we used the same procedures to assign turbulent intensities in this study. The wind-profile exponent and vertical potential temperature gradient used in the model calculations are characteristic of the marine air mass over the harbor and along the shoreline and are in good agreement with the mean values for the Millstone field experiments (Johnson, et al., 1975), which were conducted during hours with a marine air mass moving inland. The applicability of the Quillayute mixing depth estimates provided by NTPC (1980) and used in the model calculations cannot be checked against onsite (i.e., Port Angeles) data.

The tests of the Cramer, et al. (1975) short-term dispersion model described in Section 3 support the use of the model in the Port Angeles area and are consistent with the confidence intervals for the model as determined by previous studies for EPA of SO_2 sources located in complex terrain. Confidence intervals, in contrast to confidence limits which must satisfy strict statistical criteria, simply reflect the results of direct comparisons of model predictions with air quality observations without attempting to account for the effects of sample size and other limitations as must be done in the case of estimating confidence limits. In the cases where the plume from an isolated source was simultaneously detected by two or more SO_2 monitors (which allowed us to specify the wind direction at the plume height to within 1 or 2 degrees), our short-term model yielded calculated hourly SO_2 concentrations that were, on the average, equal to the observed concentrations (see Cramer, et al., 1976). Individual calculated and observed hourly SO_2 concentrations differed by as much as a factor of two. To a large extent, we believe that the discrepancies between the individual calculated and observed hourly concentrations were caused by errors in the source and meteorological inputs and possibly in the air quality measurements. When unadjusted surface wind directions were used in our model calculations, the calculated maximum 3-hour and 24-hour average SO_2 concentrations were, on the average, within 20 percent of the observed values (see Section 8 of Cramer, et al., 1975). Finkelstein (1976) also compared the results of the short-term model calculations in the Cramer, et al (1975) study with the results of wind-tunnel simulations of various sources in the Clairton area of Allegheny County and concluded that, "... the agreement between the two studies is surprising and reassuringly close." Our long-term dispersion model has yielded calculated annual average SO_2 concentrations within 10 percent of the observed values at all monitors where the annual average SO_2 concentrations were above the accuracy and threshold of the SO_2 monitors (Cramer, et al., 1975). In cases where the annual average SO_2 concentrations were below the threshold of the SO_2 monitors, our long-term model has yielded calculated annual average SO_2 concentrations that were within plus or minus one-half the accuracy and threshold of the SO_2 instrument (Cramer, et al., 1976 and Wilson, et al., 1977).

In summary, we believe that the maximum short-term and annual average ground-level SO_2 concentrations presented in this report for the existing and proposed sources probably are accurate to within about 20 percent for the stack and emissions parameters assumed in the model calculations. The uncertainties in the concentrations calculated beyond the areas of maximum impacts for emissions from the existing and proposed sources increase with distance from the sources because of the spatial variability of meteorological conditions in the Port Angeles area.

Thus, the concentrations calculated at the Olympic National Park Visitor Center are subject to greater uncertainty than are the concentrations calculated in the vicinity of the existing and proposed sources. Assuming that our model assumption of straight-line plume trajectories is, on the average, valid for the transport of emissions from the proposed NTPC sources to the Visitor Center, we estimate that the concentrations calculated for the Visitor Center are accurate to within about a factor of two, the accuracy generally attributed to the results of dispersion model calculations in the absence of complicating factors (AMS, 1978).

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APPENDIX A

MATHEMATICAL MODELS USED TO CALCULATE GROUND-LEVEL CONCENTRATIONS

A.1 INTRODUCTION

The computerized diffusion models described in this appendix fall into two general categories: (1) Short-term models for calculating time-averaged ground-level concentrations for averaging times of 1, 3, 8, and 24 hours; (2) Long-term models for calculating seasonal and annual ground-level concentrations. Both the short-term and long-term concentration models are modified versions of the Gaussian plume model for continuous sources described by Pasquill (1962). In the short-term model, the plume is assumed to have Gaussian vertical and lateral concentration distributions. The long-term model is a sector model similar in form to the Environmental Protection Agency's Climatological Dispersion Model (Calder, 1971) in which the vertical concentration distribution is assumed to be Gaussian and the lateral concentration distribution within a sector is rectangular (a smoothing function is used to eliminate sharp discontinuities at the sector boundaries). Vertical plume growth (σ_z) in the short-term and long-term models and lateral plume growth (σ_y) in the short-term model are calculated by using turbulent intensities in simple power-law expressions that include the effects of initial source dimensions. In both the short-term and long-term models, buoyant plume rise is calculated by means of the Briggs (1971; 1972) plume-rise formulas, modified to include the effects of downwash in the lee of the stack during periods when the wind speed at stack height equals or exceeds the stack exit velocity. An exponent law is used to adjust the surface wind speed to the source height for plume-rise calculations and to the plume stabilization height for the concentration calculations. Both the short-term and the long-term models contain provisions to account for the effects of complex terrain.

Table A-1 lists the hourly meteorological inputs required by the short-term concentration model. Lateral and vertical turbulent intensities σ'_A and σ'_E may be directly specified or may be assigned on the basis of the Pasquill stability category (see Section 3 of Cramer, et al., 1975). The Pasquill stability cateogry is determined from surface weather observations using the Turner (1964) wind-speed and solar-index values. Mixing depths may be obtained from rawinsonde or pibal measurements, or they may be assigned on the basis of tabulations of the frequency of occurrence of wind speed and mixing depth (available from the National Climatic Center for synoptic rawinsonde stations). Potential temperature gradients may be obtained from measurements or assigned on the basis of climatology.

Table A-2 lists the meteorological inputs required by the long-term concentration model. Joint-frequency distributions of wind-speed and wind-direction categories, classified according to the Pasquill stability categories, are available from the National Climatic Center. Alternately, surface wind observations may be analyzed to generate wind-frequency distributions by time-of-day categories (night, morning, afternoon and evening). Vertical turbulent intensities may be determined from a climatology of actual measurements or may be assigned on the basis of the Pasquill stability categories. Median mixing depths may be determined from the seasonal tabulations of the frequency of occurrence of wind-speed and mixing depth prepared by the National Climatic Center. Vertical potential temperature gradients may be assigned to the combinations of wind-speed and stability or time-of-day categories on the basis of climatology.

Table A-3 lists the source input parameters required by the short-term and long-term diffusion models. As shown by the table, the computerized short-term and long-term models calculate ground-level concentrations produced by emissions from stacks, building vents and roof monitors, and from area sources. Both the short-term and long-term models also use a Cartesian coordinate system (usually the Universal Transverse Mercator system) with the positive X axis directed toward the east and the positive Y axis directed toward the north.

TABLE A-1

HOURLY METEOROLOGICAL INPUTS REQUIRED BY THE SHORT-TERM CONCENTRATION MODEL

Parameter	Definition
$\bar{u}_R$	Mean wind speed at height z_R (m/sec)
θ	Mean wind direction at height z_R (deg)
p	Wind-profile exponent
σ'_A	Wind azimuth-angle standard deviation in radians
σ'_E	Wind elevation-angle standard deviation in radians
T_a	Ambient air temperature ($^{\circ}$K)
H_m	Depth of surface mixing layer (m)
$\frac{\partial\theta}{\partial z}$	Vertical potential temperature gradient ($^{\circ}$K/m)

TABLE A-2

METEOROLOGICAL INPUTS REQUIRED BY THE LONG-TERM CONCENTRATION MODEL

Parameter	Definition
$f_{i,j,k,\ell}$ (Table)	Frequency distribution of wind-speed and wind-direction categories by stability or time-of-day categories for the ℓ^{th} season
$p_{k,i}$ (Table)	Wind-profile exponent for each stability or time-of-day category and i^{th} wind-speed category
$\sigma'_{E;i,k}$ (Table)	Standard deviation of the wind-elevation angle in radians for the i^{th} wind-speed category and k^{th} stability or time-of-day category
$T_{a;k,\ell}$ (Table)	Ambient air temperature for the k^{th} stability or time-of-day category and ℓ^{th} season (°K)
$\left(\frac{\partial \theta}{\partial z}\right)_{i,k}$ (Table)	Vertical potential temperature gradient for the i^{th} wind-speed category and k^{th} stability or time-of-day category (°K/m)
$H_{m;i,k,\ell}$ (Table)	Median surface mixing depth for the i^{th} wind-speed category, k^{th} stability or time-of-day category and ℓ^{th} season (m)
$\bar{u}\,\{z_R\}_i$ (Table)	Mean wind speed at height z_R for the i^{th} wind-speed category (m/sec)

TABLE A-3

SOURCE INPUTS REQUIRED BY THE SHORT-TERM AND LONG-TERM CONCENTRATION MODELS

Parameter	Definition
Stacks	
Q	Pollutant emission rate (mass per unit time)
X, Y	X and Y coordinates of the stack (m)
z_s	Elevation above mean sea level of the base of the stack (m)
h	Stack height (m)
V	Actual volumetric emission rate (m^3/sec)
T_s	Stack exit temperature (^oK)
r	Stack inner radius (m)
Building Sources	
Q	Pollutant emission rate (mass per unit time)
X, Y	X and Y coordinates of the center of the building (m)
z_s	Elevation above mean sea level of the base of the building (m)
h	Building height (m)
L	Building length (m)
W	Building width (m)
δ	Angle measured clockwise between north and the long side of the building (deg)
Area Sources	
Q	Pollutant emission rate (mass per unit time)
X, Y	X and Y coordinates of the center of the area source (m)
z_s	Elevation above mean sea level of the area source (m)

TABLE A-3 (Continued)

Parameter	Definition
Area Sources (Continued)	
h	Characteristic vertical dimension of the area source (m)
L	Length of the area source (m)
W	Width of the area source (m)
δ	Angle measured clockwise between north and the long side of the area source (deg)

A.2 PLUME-RISE FORMULAS

The effective stack height H of a buoyant plume is given by the sum of the physical stack height h and the buoyant rise Δh. For an adiabatic or unstable atmosphere, the buoyant rise Δh_N is given by

$$\Delta h_N = \left[\frac{1}{\bar{u}\,\{h\}} \left(\frac{3F}{2\gamma_1^{\,2}} \right)^{1/3} (10h)^{2/3} \right] f \qquad \text{(A-1)}$$

where the expression in the brackets is from Briggs (1971; 1972) and

$\bar{u}\{h\}$ = the mean wind speed at the stack height h (m/sec)
γ_1 = the adiabatic entrainment coefficient ~ 0.6 (Briggs, 1972)
F = The initial buoyancy flux (m^4/sec^3)

$$= \frac{gV}{\pi} \left(1 - \frac{T_a}{T_s} \right) \qquad \text{(A-2)}$$

V = The volumetric emission rate of the stack (m^3/sec)

$= \pi\, r^2\, w$

r = inner radius of stack (m)
w = stack exit velocity (m/sec)
g = the acceleration due to gravity (m/sec^2)
T_a = the ambient air temperature (^oK)
T_s = the stack exit temperature (^oK)

The factor f, which limits the plume rise as the mean wind speed at stack height approaches or exceeds the stack exit velocity, is defined by

$$f = \left\{ \begin{array}{cl} 1 & ; \quad \bar{u}\{h\} \leq w/1.5 \\ \left(\dfrac{3w - 3\bar{u}\{h\}}{w} \right) & ; \quad w/1.5 < \bar{u}\{h\} < w \\ 0 & ; \quad \bar{u}\{h\} \geq w \end{array} \right\} \qquad \text{(A-3)}$$

The empirical correction factor f is generally not applied to stacks with Froude numbers less than about unity. The corresponding Briggs (1971) rise formula for a stable atmosphere (potential temperature gradient greater than zero) is

$$\Delta h_s = \left\{ \begin{array}{ll} \left[\dfrac{6F}{\bar{u}\{h\} \gamma_2^{\,2}\, S} \right]^{1/3} & ; \pi\ \bar{u}\{h\}\ S^{-1/2} < 10h \\ \left[\dfrac{3F}{\bar{u}\{h\} \gamma_2^{\,2}\, S} \left(1 - \cos \left(\dfrac{10 S^{1/2} h}{\bar{u}\{h\}} \right) \right) \right]^{1/3} & ; \pi\ \bar{u}\{h\}\ S^{-1/2} \geq 10h \end{array} \quad f \right\} \qquad \text{(A-4)}$$

where

γ_2 = the stable entrainment coefficient ~ 0.66 (Briggs, 1972)

$S = \dfrac{g}{T_a} \dfrac{\partial \theta}{\partial z}$

$\dfrac{\partial \theta}{\partial z}$ = vertical potential temperature gradient (^{o}K/m)

The entrainment coefficients γ_1 and γ_2 are based on the suggestions of Briggs (1972). It should be noted that Equation (A-4) does not permit the calculated stable rise Δh_S to exceed the adiabatic rise Δh_N as the atmosphere approaches a neutral stratification ($\partial\theta/\partial z$ approaches 0). A procedure of this type is recommended by Briggs (1972).

A.3 SHORT-TERM CONCENTRATION MODEL

A.3.1 Elevated Sources

The atmospheric dispersion model used to calculate hourly average ground-level concentrations downwind from an elevated continuous source is given by

$$\{\chi\}x,y = \frac{K\,Q}{\pi\,\bar{u}(H)\sigma_y\,\sigma_z}\{\text{Vertical Term}\}\,\{\text{Lateral Term}\}\,\{\text{Decay Term}\} \quad \text{(A-5)}$$

where

K = scaling coefficient to convert input parameters to dimensionally consistent units

Q = source emission rate (mass per unit time)

$\bar{u}(H)$ = mean wind speed at the plume stabilization height H (m/sec)

σ_y,σ_z = standard deviations of the lateral and vertical concentration distributions at downwind distance x (m)

The Vertical Term refers to the plume expansion in the vertical or z direction and includes a multiple reflection term that limits cloud growth to the surface mixing layer.

$$\{\text{Vertical Term}\} = \left\{\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] + \sum_{n=1}^{\infty}\left[\exp\left[-\frac{1}{2}\left(\frac{2n\,H_m + H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{2n\,H_m - H}{\sigma_z}\right)^2\right]\right]\right\} \quad \text{(A-6)}$$

where H_m is the depth of the surface mixing layer. The exponential terms in the infinite series in Equation (A-6) rapidly approach zero near the source. At the downwind distance where the exponential terms exceed exp(-10) for n equal 3, the plume has become approximately uniformly mixed within the surface mixing layer. In order to shorten computer computation time, Equation (A-6) is changed to the form

$$\{\text{Vertical Term}\} = \frac{\sqrt{2\pi}\,\sigma_z}{2H_m} \tag{A-7}$$

beyond this point. Equation (A-7) changes the form of the vertical concentration distribution from Gaussian to rectangular. If H exceeds H_m, the Vertical Term is set equal to zero which results in a zero value for the ground-level concentration.

The Lateral Term refers to the crosswind expansion of the plume and is given by the expression

$$\{\text{Lateral Term}\} = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \tag{A-8}$$

where y is the crosswind distance from the plume centerline to the point at which concentration is calculated.

The Decay Term, which accounts for the possibility of pollutant removal by physical or chemical processes, is of the form

$$\{\text{Decay Term}\} = \exp\left[-\psi\, x/\bar{u}\{H\}\right] \tag{A-9}$$

where

ψ = the washout coefficient Λ (sec^{-1}) for precipitation scavenging

$= \frac{0.692}{T_{1/2}}$, where $T_{1/2}$ is the pollutant half life in seconds for physical or chemical removal

= 0 for no depletion (ψ is automatically set to zero by the computer program unless otherwise specified)

In the model calculations, the observed mean wind speed $\bar{u}_R$ is adjusted from the measurement height z_R to the source height h for plume-rise calculations and to the stabilization height H for the concentration calculations by a wind-profile exponent law

$$\bar{u}\{z\} = \bar{u}\{z_R\} \left(\frac{z}{z_R}\right)^p \qquad \text{(A-10)}$$

The exponent p, which is assigned on the basis of atmospheric stability, ranges from about 0.1 for very unstable conditions to about 0.4 for very stable conditions.

According to the derivation in the report by Cramer, et al. (1972), the standard deviation of the lateral concentration distribution σ_y is given by the expression

$$\sigma_y\{x\} = \sigma'_A \, x_{ry} \left[\frac{x + x_y - x_{ry}(1-\alpha)}{\alpha x_{ry}}\right]^{\alpha} \qquad \text{(A-11)}$$

$$x_y = \left\{ \begin{array}{ll} \dfrac{\sigma_{yR}}{\sigma'_A} - x_R & ; \quad \dfrac{\sigma_{yR}}{\sigma'_A} \le x_{ry} \\[2ex] \alpha x_{ry} \left(\dfrac{\sigma_{yR}}{x_{ry} \; \sigma'_A}\right)^{1/\alpha} - x_R + x_{ry}(1-\alpha) & ; \quad \dfrac{\sigma_{yR}}{\sigma'_A} > x_{ry} \end{array} \right\} \qquad \text{(A-12)}$$

where

σ'_A = the standard deviation of the wind-azimuth angle in radians

x_{ry} = distance over which rectilinear plume expansion occurs downwind from an ideal point source (~50 meters)

σ_{yR} = the standard deviation of the lateral concentration distribution at downwind distance x_R (m)

α = the lateral diffusion coefficient (~0.9)

The virtual distance x_y is not permitted to be less than zero. The lateral turbulent intensity σ'_A may be specified directly or may be assigned on the basis of the Pasquill stability category.

Following the derivation of Cramer, et al. (1972) and setting the vertical diffusion coefficient β equal to unity, the standard deviation of the vertical concentration distribution σ_z is given by the expression

$$\sigma_z\{x\} = \sigma'_E \left(x + x_z\right) \tag{A-13}$$

$$x_z = \begin{cases} \dfrac{\sigma_{zR}}{\sigma'_E} - x_R & ; \dfrac{\sigma_{zR}}{\sigma'_E} \geq x_R \\[2ex] 0 & ; \dfrac{\sigma_{zR}}{\sigma'_E} < x_R \end{cases} \tag{A-14}$$

where

σ'_E = standard deviation of the wind-elevation angle in radians

σ_{zR} = the standard deviation of the vertical concentration distribution at downwind distance x_R (m)

The vertical turbulent intensity σ'_E may also be obtained from direct measurements or may be assigned according to the Pasquill stability categories. When σ'_E values corresponding to the Pasquill stability categories are entered in Equation (A-13), the resulting curves will differ from the corresponding Pasquill-Gifford curves in that Equation (A-13) assumes rectilinear expansion at all downwind distances. Thus, σ_z values obtained from Equation (A-13) will be smaller than the values obtained from the Pasquill-Gifford A and B curves and larger than the values obtained from the D, E and F curves at long downwind distances. However, the multiple reflection term in Equation (A-6), which confines the plume to the surface mixing layer, accounts for the behavior of the D, E and F curves (decrease in the expansion rate with distance) in a manner that may be related to the meteorology of the area.

Following the recommendations of Briggs (1972), the lateral and vertical standard deviations of a stabilized buoyant plume are defined by

$$\sigma_{yR} = \sigma_{zR} = \frac{0.5\ \Delta h}{2.15} \tag{A-15}$$

The downwind distance to stabilization x_R is given by

$$x_R = \begin{cases} 10h & ; \dfrac{\partial\theta}{\partial z} \le 0 \\ \pi\ \bar{u}(h)\ S^{-1/2} & ; \dfrac{\partial\theta}{\partial z} > 0 \text{ and } \pi\ \bar{u}(h)\ S^{-1/2} < 10h \\ 10h & ; \dfrac{\partial\theta}{\partial z} > 0 \text{ and } \pi\ \bar{u}(h)\ S^{-1/2} \ge 10h \end{cases} \tag{A-16}$$

A.3.2 Application of the Short-Term Model to Low-level Emissions

The short-term diffusion model in Section A.3.1 may be used to calculate ground-level concentrations resulting from low-level emissions such as losses through building vents. These emissions are rapidly distributed by the cavity circulation of the building wake and quickly assume the dimensions of the building. Ground-level concentrations are calculated by setting the buoyancy parameter F equal to zero. The standard deviation of the lateral concentration distribution at the source σ_{yo} is defined by the building crosswind dimension y_o divided by 4.3. The standard deviation of the vertical concentration distribution at the source is obtained by dividing the building height by 2.15. The initial dimensions σ_{yo} and σ_{zo} are assumed to be applicable at the downwind edge of the building. These procedures are in good agreement with the results of recent wind-tunnel experiments reported by Huber and Snyder (1976). It should be noted that separate turbulent intensities σ'_A and σ'_E may be defined for the low-level sources to account for the effects of surface roughness elements and heat sources.

A.3.3 Short-Term Concentration Model for Area Sources

The atmospheric dispersion model used to calculate ground-level concentrations at downwind distance x from the downwind edge of an area source is given by the expression

$$\chi\{x, y\} = \frac{K\,Q}{\sqrt{2\pi}\;\bar{u}\{h\}\;\sigma_z\{x\}\;y_o}\;\{\text{Vertical Term}\} \cdot \{\text{Lateral Term}\}\;\{\text{Decay Term}\} \qquad \text{(A-17)}$$

where

Q = area source strength in units of mass per unit time

y_o = crosswind source dimension (m)

$$\sigma_z\{x\} = \begin{cases} \dfrac{\sigma'_E \; x_o}{\ln\left[\dfrac{\sigma'_E(x+x_o)+h}{\sigma'_E(x)+h}\right]} & ; \quad x < 3\; x_o \\[2em] \sigma'_E(x+x_o/2)+h & ; \quad x \geq 3\; x_o \end{cases} \tag{A-18}$$

x_o = alongwind dimension of the area source (m)
h = the characteristic height of the area source (m)

The Vertical Term for an area source is given by

$$\{\text{Vertical Term}\} = \begin{cases} 1+2\displaystyle\sum_{n=1}^{3} \exp\left[-\frac{1}{2}\left(\frac{2n\; H_m}{\sigma_x\{x\}}\right)^2\right] & ; \quad \dfrac{1}{2}\left(\dfrac{6H_m}{\sigma_z\{x\}}\right)^2 \geq 10 \\[2em] \dfrac{\sqrt{2\pi}\; \sigma_z\{x\}}{2H_m} & ; \quad \dfrac{1}{2}\left(\dfrac{6H_m}{\sigma_z\{x\}}\right)^2 < 10 \end{cases} \tag{A-19}$$

The Lateral Term is given by the expression

$$\{\text{Lateral Term}\} = \left\{\text{erf}\left[\frac{y_o/2+y}{\sqrt{2}\;\sigma_y\{x\}}\right] + \text{erf}\left[\frac{y_o/2-y}{\sqrt{2}\;\sigma_y\{x\}}\right]\right\} \tag{A-20}$$

where

y_o = crosswind dimension of the area source (m)
y = crosswind distance from the centerline of the area source (m)

and

$$\sigma_y\{x\} = \sigma'_A \; (x+x_o/2) \qquad \text{(A-21)}$$

The Decay Term is given by Equation (A-9) above.

The concentration at points interior to the area source is given by

$$\chi\{x'\} = \frac{2\;K\;Q}{\sqrt{2\pi}\;\bar{u}\{h\}\;x_o\;y_o\;\sigma'_E} \left\{ \ln \left[\frac{\sigma'_E\;(x'+1)+h}{\sigma'_E + h} \right] \right\} \{\text{Vertical Term}\} \qquad \text{(A-22)}$$

where

x' = distance downwind from the upwind edge of the area source (m)

A.4 LONG-TERM CONCENTRATION MODEL

A.4.1 Elevated Sources

The atmospheric dispersion model for elevated point and volume sources is similar in form to the Air Quality Display Model (Environmental Protection Agency, 1969) and the Climatological Dispersion Model (Calder, 1971). In the model, the area surrounding a continuous source of pollutants is divided into sectors of equal angular width corresponding to the class intervals of the seasonal and annual frequency distributions of wind direction. The emission rate during a season or year is partitioned according to the relative wind-direction frequencies. Ground-level concentration fields for each source are translated to a common reference coordinate grid system and summed to obtain the total due to all emissions. For a single source, the mean seasonal concentration at a point (r, θ) is given by

$$\chi_\ell\{r, \theta\} = \frac{2\ K\ Q}{\sqrt{2\pi}\ r\ \Delta\theta'} \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\left\{H_{i,k,\ell}\right\} \sigma_{z;i,k,\ell}}\ S\{\theta\}\ V_{i,k,\ell} \right.$$

$$\left. \exp\left[- \psi\ r/\bar{u}_i\ H_{i,k,\ell}\{ \right] \right] \tag{A-23}$$

$$V_{i,k,\ell} = \exp\left[-\frac{1}{2}\left(\frac{H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2 \right] + \sum_{n=1}^{\infty} \left\{ \exp\left[-\frac{1}{2}\left(\frac{2n\ H_{m;i,k,\ell} - H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2 \right] \right.$$

$$\left. + \exp\left[-\frac{1}{2}\left(\frac{2n\ H_{m;i,k,\ell} + H_{i,k,\ell}}{\sigma_{z;i,k,\ell}}\right)^2 \right] \right\} \tag{A-24}$$

where

$f_{i,j,k,\ell}$ = frequency of occurrence of the i^{th} wind-speed category, j^{th} wind-direction category and k^{th} stability or time-of-day category for the ℓ^{th} season

$\Delta\theta'$ = the sector width in radians

$S\{\theta\}$ = a smoothing function

$$S\{\theta\} = \begin{cases} \dfrac{\Delta\theta' - |\theta_j' - \theta'|}{\Delta\theta'} & ; \quad |\theta_j' - \theta'| \le \Delta\theta' \\[2ex] 0 & ; \quad |\theta_j' - \theta'| > \Delta\theta' \end{cases} \tag{A-25}$$

θ_j' = the angle measured in radians from north to the centerline of the j^{th} wind-direction sector

θ' = the angle measured in radians from north to the point (r,θ)

As with the short-term model, the Vertical Term given by Equation (A-24) is changed to the form

$$V_{i,k,\ell} = \frac{\sqrt{2\pi}\,\sigma_{z;i,k,\ell}}{2H_{m;i,k,\ell}} \tag{A-26}$$

when the exponential terms in Equation (A-24) exceed exp(-10) for n equal 3. The remaining terms in Equations (A-23) are identical to those previously defined in Section A.3.1 for the short-term model, except that the turbulent intensities and potential temperature gradients may be separately assigned to each wind-speed and/or stability (or time-of-day) category; the ambient air temperatures may be separately assigned to each stability (or time-of-day) category for each season; and the surface mixing depths may be separately assigned to each wind-speed and/or stability (or time-of-day) category for each season.

As shown by Equation (A-25), the rectangular concentration distribution within a given angular sector is modified by the function $S\{\theta\}$ which smoothes discontinuities in the concentration at the boundaries of adjacent sectors. The centerline concentration in each sector is unaffected by contributions from adjacent sectors. At points off the sector centerline, the concentration is weighted function of the concentration at the centerline of the sector in which the calculation is being made and the concentration at the centerline of the nearest adjoining sector.

The mean annual concentration at the point (r,θ) is calculated from the seasonal concentrations using the expression

$$\chi_a\{r,\theta\} = \frac{1}{4}\sum_{\ell=1}^{4} \chi_\ell\{r,\theta\} \tag{A-27}$$

A.4.2 Application of the Long-Term Model to Low-Level Emissions

Long-term ground-level concentrations produced by low-level emissions are calculated from Equation (A-23) by setting the buoyancy parameter F equal to zero. The standard deviation of the vertical concentration distribution at the downwind edge of the building σ_{zo} is defined as the building height divided by 2.15. Separate vertical turbulent intensities σ'_E may be defined for the low-level sources to account for the effects of surface heat sources and roughness elements. A virtual point source is used to account for the initial lateral dimension of the source in a manner identical to that described below for area sources.

A.4.3 Long-Term Concentration Model for Area Sources

The mean seasonal concentration at downwind distance r with respect to the center of an area source is given by the expression

$$\chi_\ell\{r > r_o\} = \frac{2\,K\,Q}{\sqrt{2\pi}\;R\;\Delta\theta'} \left\{ \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\{h\}\;\sigma_{z;i,k}} \quad S\{\theta\} \quad V_{i,k,\ell} \right] \right. \tag{A-28}$$

$$\left. \exp\left[-\psi\left(r' - r_o\right)/\bar{u}_i\{h\} \right] \right\}$$

where

R = radial distance from the virtual point source to the receptor

$= \left(\left(r' + x_y\right)^2 + y^2\right)^{1/2}$

r' = distance from source center to receptor, measured along the sector centerline (m)

r_o = effective source radius (m)

y = lateral distance from the sector centerline to the receptor (m)

x_y = lateral virtual distance (m)

$$= r_o \cot \frac{\Delta\theta'}{2} \tag{A-29}$$

$$\sigma_{z;i,k} = \left\{ \begin{array}{ll} \dfrac{2\sigma'_{E;i,k}\ r_o}{\ln\left[\dfrac{\sigma'_{E;i,k}(r'+r_o)+h}{\sigma'_{E;i,k}(r'-r_o)+h}\right]} & ;\ r_o < r' < 6r_o \\ \\ \sigma'_{E;i,k} r' + h & ;\ r' \geq 6r_o \end{array} \right\} \tag{A-30}$$

$$V_{i,k,\ell} = \left\{ \begin{array}{ll} 1+2\displaystyle\sum_{n=1}^{3} \exp\left[-\frac{1}{2}\left(\frac{2n\ H_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2\right] & ;\ \dfrac{1}{2}\left(\dfrac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2 \geq 10 \\ \\ \dfrac{\sqrt{2\pi}\ \sigma_{z;i,k}}{H_{m;i,k,\ell}} & ;\ \dfrac{1}{2}\left(\dfrac{6H_{m;i,k,\ell}}{\sigma_{z;i,k}}\right)^2 < 10 \end{array} \right\} \tag{A-31}$$

and the remaining parameters are identical to those previously defined.

For points interior to the area source, the seasonal average concentration is given by the expression:

$$\chi_\ell\{r \leq r_o\} = \frac{2\ K\ Q}{\sqrt{2\pi}\ x_o\ y_o} \sum_{i,j,k} \left[\frac{f_{i,j,k,\ell}}{\bar{u}_i\{h\}\ \sigma'_{E;i,k}} \ln\left[\frac{\sigma'_{E;i,k}(r''+1)+h}{\sigma'_{E;i,k}+h}\right] V_{i,k,\ell} \right] \tag{A-32}$$

where

r" = the downwind distance, measured along the sector centerline from the upwind edge of the area source (m)

A.5 APPLICATION OF THE SHORT-TERM AND LONG-TERM CONCENTRATION MODELS IN COMPLEX TERRAIN

The short-term and long-term concentration models described in Sections A.3 and A.4 are strictly applicable only for flat terrain where the base of the stack (or the building source) and the ground surface downwind from the source are at the same elevation. However, both models may also be applied to complex terrain by defining effective stabilization heights and mixing depths. The following assumptions are made in the model calculations for complex terrain:

- The top of the surface mixing layer extends over the calculation grid at a constant height above mean sea level

- Ground-level concentrations at all grid points above the top of the surface mixing layer are zero

- Plumes that stabilize above the top of the surface mixing layer do not contribute to ground-level concentrations at any grid point (this assumption also applies to flat terrain)

In order to determine whether the stabilized plume is contained within the surface mixing layer, it is necessary to calculate the mixing depth $H_m^*\{z_s\}$ at the source from the relationship

$$H_m^*\{z_s\} = \left(H_m + z_a - z_s\right) \qquad \text{(A-33)}$$

where

H_m = the depth of the surface mixing layer measured at a point with elevation z_a above mean sea level

z_s = the height above mean sea level of the source

Equation (A-33) is represented schematically in Figure A-1. As shown by the figure, the actual top of the surface mixing layer is assumed to remain at a constant elevation above mean sea level. If the height H of the stabilized plume above the base of the stack is less than or equal to $H_m^*\{z_s\}$, the plume is defined to be contained within the surface mixing layer.

The height H_o of the stabilized plume above mean sea level is given by the sum of the height H of the stabilized plume above the base of the stack and the elevation z_s of the base of the stack. At any elevation z above mean sea level, the effective height $H'\{z\}$ of the plume centerline above the terrain is then given by

$$H'\{z\} = \begin{Bmatrix} H_o - z \; ; & H_o - z \geq 0 \\ \\ 0 \; ; & H_o - z < 0 \end{Bmatrix} \qquad \text{(A-34)}$$

The effective mixing depth $H_m'\{z\}$ above a point at elevation z above mean sea level is defined by

$$H_m'\{z\} = \begin{Bmatrix} H_m \; ; & z \geq z_a \\ \\ H_m + z_a - z \; ; & z < z_a \end{Bmatrix} \qquad \text{(A-35)}$$

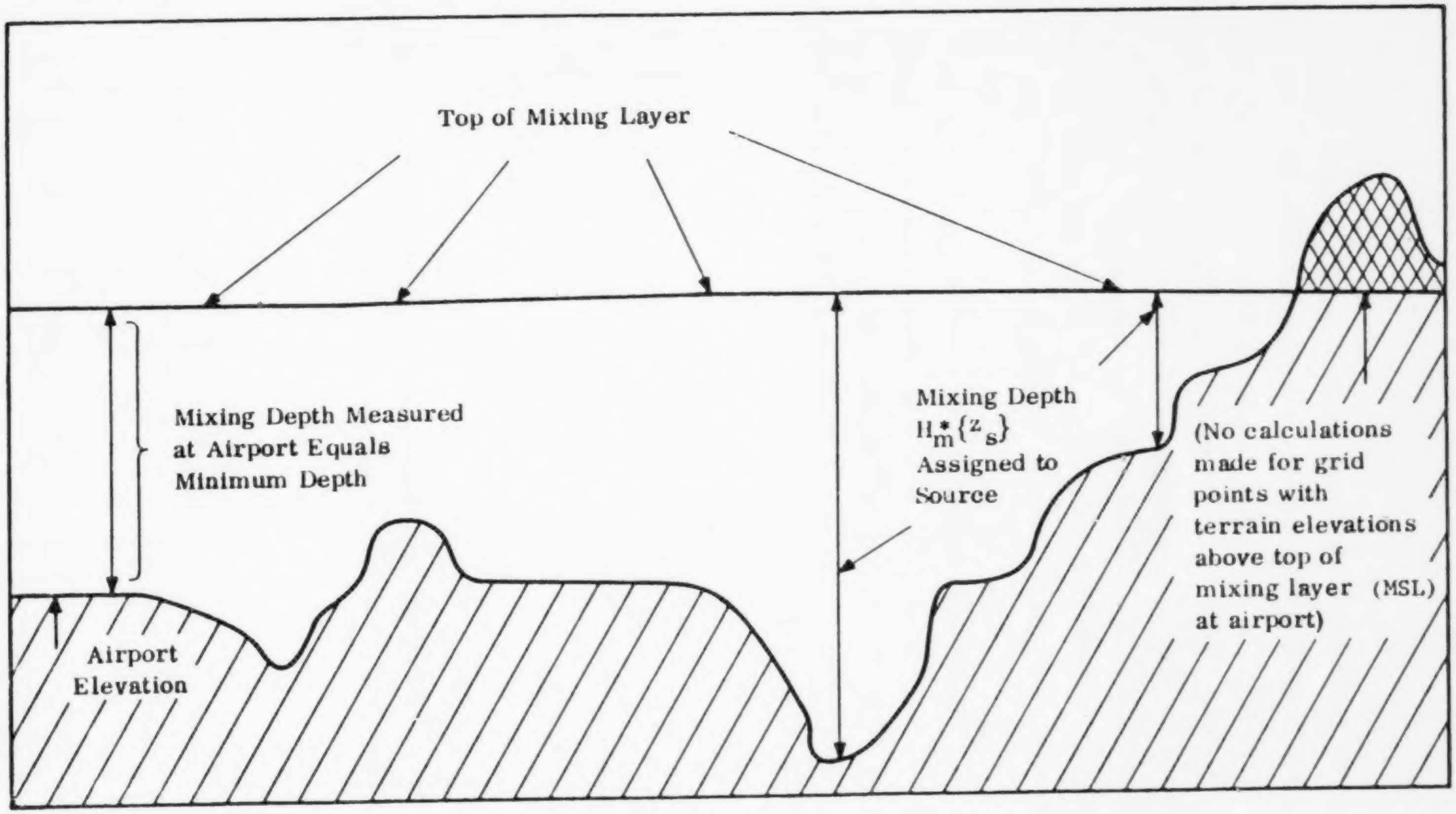

FIGURE A-1. Mixing depth $H^*_m\{z_s\}$ used to determine whether the stabilized plume is contained within the surface mising layer.

Figure A-2 illustrates the assumptions implicit in Equation (A-35). For grid points at elevations below the airport elevation, the effective mixing depth $H'_m\{z\}$ is allowed to increase in a manner consistent with Figure A-1. However, in order to prevent a physically unrealistic compression of plumes as they pass over elevated terrain, the effective mixing depth is not permitted to be less than the mixing depth measured at the airport. It should be noted that the concentration is set equal to zero for grid points above the actual top of the mixing layer (see Figure A-1).

The terrain adjustment procedures also assume that the mean wind speed at any given height above sea level is constant. Thus, the wind speed $\bar{u}_R$ above the surface at a point with elevation z_a above mean sea level is adjusted to the stack height for the plume-rise calculations by the relationship

$$\bar{u}\{h\} = \left\{ \begin{array}{ll} \bar{u}_R \left(\dfrac{h_o - z_a}{z_R} \right)^p & ; \quad h_o \geq z_a + z_R \\ \\ \bar{u}_R & ; \quad h_o < z_a + z_R \end{array} \right\} \qquad \text{(A-36)}$$

where h_o is the height above mean sea level of the top of the stack. Similarly, the wind speed $\bar{u}\{H\}$ used in the concentration calculations is given by

$$\bar{u}\{H\} = \left\{ \begin{array}{ll} \bar{u}_R \left(\dfrac{H_o - z_a}{z_R} \right)^p & ; \quad H_o \geq z_a + z_R \\ \\ \bar{u}_R & ; \quad H_o < z_a + z_R \end{array} \right\} \qquad \text{(A-37)}$$

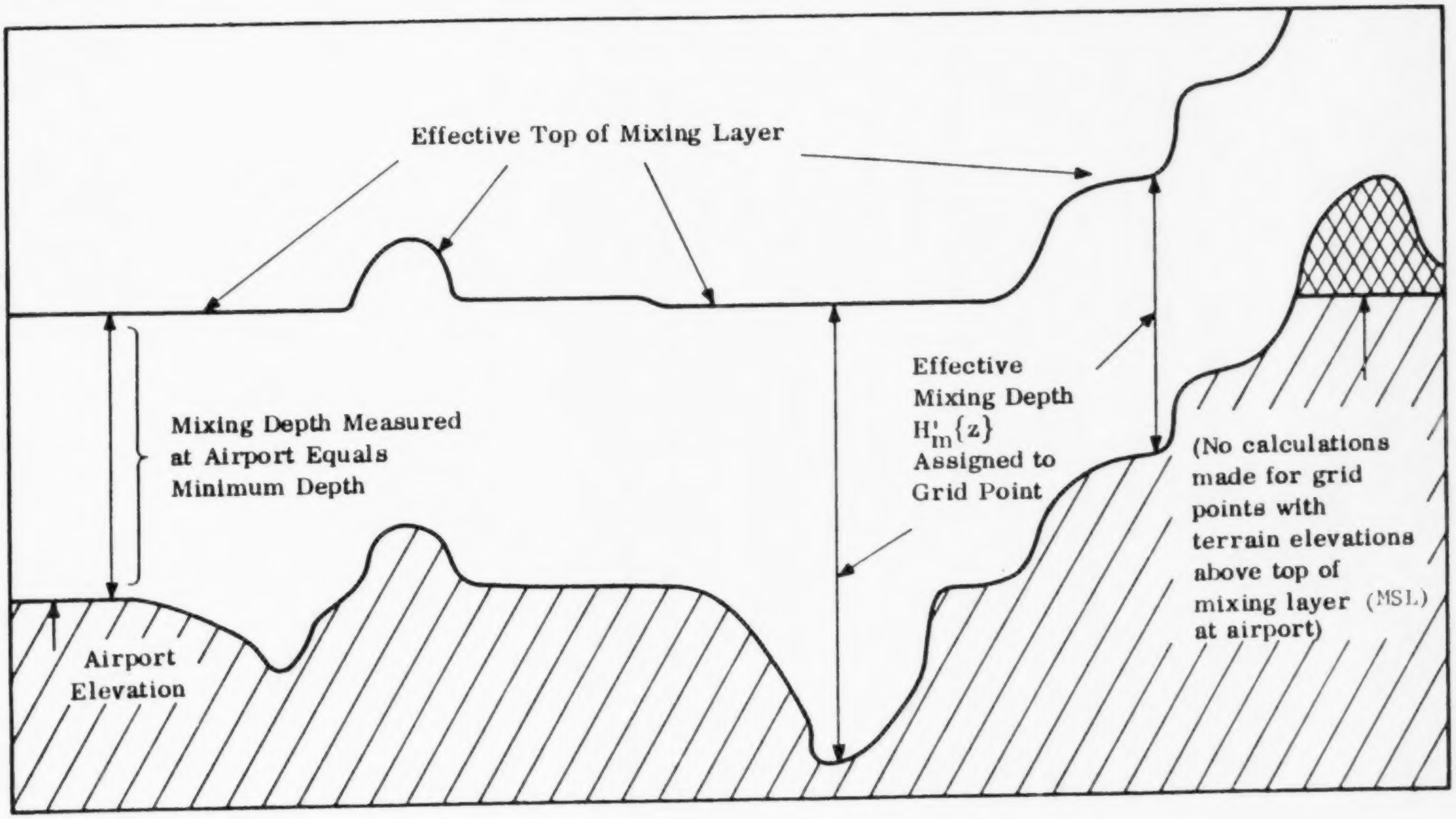
Effective Top of Mixing Layer
Mixing Depth Measured at Airport Equals Minimum Depth
Effective Mixing Depth $H'_m\{z\}$ Assigned to Grid Point
(No calculations made for grid points with terrain elevations above top of mixing layer (MSL) at airport)
Airport Elevation

FIGURE A-2. Effective mixing depth $H'_m\{z\}$assigned to grid points for the concentration calculations.

APPENDIX B

SUPPLEMENTARY METEOROLOGICAL DATA

Tables B-1 through B-5 list the seasonal and annual summaries of the joint frequency of occurrence of wind-speed and wind-direction categories, classified according to the Pasquill stability categories, for the Ediz Hook 10-meter meteorological tower during the period 15 August 1978 to 15 August 1979. As explained in Section 2.2, Whidbey Island cloud cover data in combination with the Ediz Hook tower wind speeds were used to assign stability to each hour following the Turner (1964) definitions of the Pasquill stability categories. The hourly meteorological inputs for the 24-hour and 3-hour periods considered in the attainment status analysis are listed in chronological order in Tables B-6 and B-7, respectively. These inputs were also used in the Prevention of Significant Deterioration (PSD) Increment calculations for the Class II areas. The hourly meteorological inputs for the "worst-case" 24-hour and 3-hour periods for the PSD calculations for the Class I area (Olympic National Park) are listed in chronological order in Tables B-8 and B-9, respectively.

TABLE B-1

WINTER JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE EDIZ HOOK 10-METER TOWER

DIRECTION	STABILITY CATEGORY A			STABILITY CATEGORY B				STABILITY CATEGORY C						
	WIND SPEED (M/SEC)			WIND SPEED (M/SEC)				WIND SPEED (M/SEC)						
(SECTOR)	0-1 5	1 6-3 0	TOTAL	0-1 5	1 6-3 0	3 1-5 1	TOTAL	0-1 5	1 6-3 0	3 1-5 1	5 2-8 2	8 3-10 8	>10 8	TOTAL
N	0000	0000	0000	0000	0000	0000	0000	0005	0010	0010	0000	0000	0000	0024
NNE	0000	0000	0000	0010	0000	0000	0010	0010	0015	0019	0000	0000	0000	0044
NE	0000	0000	0000	0010	0000	0000	0010	0000	0053	0029	0000	0000	0000	0083
ENE	0000	0000	0000	0005	0000	0000	0005	0005	0019	0073	0000	0000	0000	0097
E	0000	0000	0000	0005	0000	0000	0005	0015	0034	0053	0000	0000	0000	0102
ESE	0000	0000	0000	0010	0000	0000	0010	0010	0019	0024	0000	0000	0000	0053
SE	0000	0000	0000	0005	0000	0000	0005	0005	0034	0015	0000	0000	0000	0053
SSE	0000	0000	0000	0000	0000	0000	0000	0015	0000	0000	0000	0000	0000	0015
S	0000	0000	0000	0010	0000	0000	0010	0010	0010	0000	0000	0000	0000	0019
SSW	0000	0000	0000	0005	0000	0000	0005	0010	0000	0000	0000	0000	0000	0010
SW	0000	0000	0000	0000	0000	0000	0000	0005	0000	0005	0000	0000	0000	0010
WSW	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
W	0000	0000	0000	0005	0000	0000	0005	0015	0010	0000	0000	0000	0000	0024
WNW	0000	0000	0000	0000	0000	0000	0000	0000	0010	0000	0000	0000	0000	0010
NW	0000	0000	0000	0000	0000	0000	0000	0015	0015	0000	0000	0000	0000	0029
NNW	0000	0000	0000	0000	0000	0000	0000	0019	0024	0005	0000	0000	0000	0049
TOTAL	0000	0000	0000	0063	0000	0000	0063	0136	0252	0233	0000	0000	0000	0621

DIRECTION	STABILITY CATEGORY D							STABILITY CATEGORY E			STABILITY CATEGORY F			WINTER WIND DIRECTION DISTRIBUTION
	WIND SPEED (M/SEC)							WIND SPEED (M/SEC)			WIND SPEED (M/SEC)			
(SECTOR)	0-1 5	1 6-3 0	3 1-5 1	5 2-8 2	8 3-10 8	>10 8	TOTAL	1 6-3 0	3.1-5 1	TOTAL	0-1 5	1 6-3 0	TOTAL	
N	0010	0034	0044	0078	0015	0000	0180	0005	0015	0019	0005	0015	0019	0243
NNE	0015	0053	0087	0063	0000	0000	0218	0010	0063	0073	0000	0010	0010	0354
NE	0010	0097	0087	0063	0019	0000	0267	0010	0073	0083	0000	0024	0024	0466
ENE	0019	0097	0073	0049	0000	0000	0238	0034	0059	0092	0000	0019	0019	0451
E	0039	0209	0126	0039	0010	0010	0432	0044	0034	0078	0000	0024	0024	0641
ESE	0010	0199	0112	0053	0005	0005	0383	0044	0063	0107	0005	0010	0015	0568
SE	0044	0141	0155	0019	0000	0000	0359	0063	0087	0150	0010	0015	0024	0592
SSE	0102	0160	0073	0019	0000	0000	0354	0102	0175	0277	0053	0170	0223	0869
S	0126	0165	0044	0000	0000	0000	0335	0194	0068	0262	0058	0296	0354	0981
SSW	0053	0150	0044	0000	0005	0000	0262	0126	0034	0160	0063	0229	0291	0728
SW	0087	0257	0160	0029	0005	0000	0539	0155	0097	0252	0053	0296	0350	1150
WSW	0039	0194	0117	0063	0073	0044	0519	0044	0024	0068	0015	0049	0063	0650
W	0068	0155	0345	0340	0155	0049	1112	0083	0024	0107	0019	0019	0039	1286
WNW	0010	0078	0078	0146	0117	0068	0495	0015	0005	0019	0005	0015	0019	0544
NW	0010	0117	0044	0049	0015	0000	0233	0010	0010	0019	0000	0010	0010	0291
NNW	0000	0058	0010	0024	0010	0000	0112	0000	0015	0015	0000	0010	0010	0184
TOTAL	0641	2165	1597	1034	0427	0175	6039	0937	0845	1782	0266	1209	1495	

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TABLE B-2

SPRING JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE EDIZ HOOK 10-METER TOWER

DIRECTION	STABILITY CATEGORY A			STABILITY CATEGORY B				STABILITY CATEGORY C						
	WIND SPEED (M/SEC)			WIND SPEED (M/SEC)				WIND SPEED (M/SEC)						
(SECTOR)	0-1 5	1 6-3 0	TOTAL	0-1 5	1 6-3 0	3 1-5 1	TOTAL	0-1 5	1 6-3 0	3 1-5 1	5 2-8 2	8 3-10 8	>10 8	TOTAL
N	0000	0000	0000	0014	0014	0000	0027	0005	0014	0005	0000	0000	0000	0023
NNE	0000	0000	0000	0023	0023	0000	0046	0005	0009	0000	0000	0000	0000	0014
NE	0000	0000	0000	0000	0073	0009	0082	0023	0068	0027	0000	0000	0000	0119
ENE	0000	0000	0000	0023	0082	0005	0109	0000	0059	0036	0000	0000	0000	0096
E	0005	0014	0018	0027	0146	0000	0173	0005	0055	0032	0000	0000	0000	0091
ESE	0000	0005	0005	0018	0073	0014	0105	0018	0068	0023	0000	0000	0000	0109
SE	0000	0005	0005	0023	0050	0005	0078	0009	0046	0005	0000	0000	0000	0059
SSE	0000	0000	0000	0018	0014	0000	0032	0018	0018	0005	0000	0000	0000	0041
S	0000	0000	0000	0023	0000	0000	0023	0046	0018	0005	0000	0000	0000	0068
SSW	0000	0000	0000	0009	0005	0000	0014	0005	0000	0000	0000	0000	0000	0005
SW	0000	0000	0000	0005	0005	0000	0009	0023	0005	0000	0000	0000	0000	0027
WSW	0000	0000	0000	0009	0000	0000	0009	0005	0005	0000	0000	0000	0000	0009
W	0000	0000	0000	0000	0005	0005	0009	0005	0023	0050	0005	0000	0000	0082
WNW	0000	0000	0000	0005	0027	0023	0055	0005	0023	0132	0041	0000	0000	0201
NW	0000	0005	0005	0005	0046	0046	0096	0000	0082	0023	0000	0000	0000	0105
NNW	0000	0000	0000	0005	0046	0014	0064	0014	0027	0000	0000	0000	0000	0041
TOTAL	0005	0027	0032	0205	0607	0119	0931	0162	0520	0342	0046	0000	0000	1090

DIRECTION	STABILITY CATEGORY D							STABILITY CATEGORY E			STABILITY CATEGORY F			SPRING WIND DIRECTION DISTRIBUTION
	WIND SPEED (M/SEC)							WIND SPEED (M/SEC)			WIND SPEED (M/SEC)			
(SECTOR)	0-1 5	1 6-3 0	3 1-5 1	5 2-8 2	8 3-10 8	>10 8	TOTAL	1 6-3 0	3 1-5 1	TOTAL	0-1 5	1 6-3 0	TOTAL	
N	0000	0027	0009	0005	0000	0000	0041	0000	0000	0000	0009	0000	0009	0100
NNE	0009	0023	0018	0000	0000	0000	0050	0000	0000	0000	0000	0000	0000	0109
NE	0032	0082	0018	0009	0000	0000	0141	0018	0000	0018	0005	0009	0014	0374
ENE	0014	0068	0027	0023	0000	0000	0132	0005	0005	0009	0005	0005	0009	0356
E	0018	0091	0027	0005	0000	0000	0141	0014	0000	0014	0014	0009	0023	0461
ESE	0009	0027	0014	0000	0000	0000	0050	0018	0009	0027	0014	0032	0046	0342
SE	0027	0068	0014	0000	0000	0000	0109	0050	0014	0064	0032	0046	0078	0392
SSE	0032	0073	0014	0005	0000	0000	0123	0041	0046	0087	0032	0091	0123	0406
S	0023	0096	0000	0000	0000	0000	0119	0041	0036	0078	0064	0201	0265	0552
SSW	0018	0096	0014	0000	0000	0000	0128	0091	0032	0123	0078	0146	0224	0493
SW	0023	0187	0100	0018	0000	0000	0328	0201	0050	0251	0046	0301	0347	0963
WSW	0041	0119	0196	0128	0000	0000	0484	0064	0100	0164	0027	0064	0091	0757
W	0009	0105	0452	0993	0265	0009	1834	0032	0278	0310	0018	0082	0100	2336
WNW	0014	0114	0319	0547	0255	0032	1282	0036	0059	0096	0023	0018	0041	1674
NW	0000	0105	0078	0036	0018	0018	0255	0009	0000	0009	0018	0009	0027	0497
NNW	0018	0046	0000	0000	0000	0000	0064	0005	0000	0005	0005	0009	0014	0187
TOTAL	0287	1328	1300	1770	0539	0059	5283	0625	0630	1255	0388	1022	1410	

TABLE B-3

SUMMER JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE EDIZ HOOK 10-METER TOWER

DIRECTION	STABILITY CATEGORY A			STABILITY CATEGORY B				STABILITY CATEGORY C						
	WIND SPEED (M/SEC)			WIND SPEED (M/SEC)				WIND SPEED (M/SEC)						
(SECTOR)	0-1.5	1.6-3.0	TOTAL	0-1.5	1.6-3.0	3.1-5.1	TOTAL	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8	TOTAL
N	0000	0005	0005	0019	0010	0005	0034	0015	0024	0000	0000	0000	0000	0039
NNE	0000	0000	0000	0029	0015	0005	0049	0010	0005	0005	0000	0000	0000	0019
NE	0000	0005	0005	0034	0029	0019	0082	0015	0015	0019	0000	0000	0000	0048
ENE	0000	0019	0019	0029	0024	0000	0053	0005	0010	0005	0000	0000	0000	0019
E	0000	0010	0010	0039	0044	0000	0082	0010	0029	0000	0000	0000	0000	0039
ESE	0005	0019	0024	0048	0049	0000	0097	0010	0034	0000	0000	0000	0000	0044
SE	0005	0019	0024	0029	0010	0000	0039	0010	0015	0005	0000	0000	0000	0029
SSE	0000	0000	0000	0024	0005	0000	0029	0000	0010	0000	0000	0000	0000	0010
S	0000	0005	0005	0015	0000	0000	0015	0005	0000	0000	0000	0000	0000	0005
SSW	0000	0000	0000	0005	0000	0000	0005	0015	0005	0000	0000	0000	0000	0019
SW	0000	0000	0000	0000	0005	0000	0005	0010	0000	0000	0000	0000	0000	0010
WSW	0000	0005	0005	0010	0000	0010	0019	0010	0010	0015	0010	0000	0000	0044
W	0000	0000	0000	0015	0000	0010	0024	0015	0039	0087	0010	0010	0000	0160
WNW	0000	0005	0005	0019	0034	0058	0111	0010	0039	0160	0174	0034	0015	0431
NW	0000	0005	0005	0019	0073	0111	0203	0000	0063	0174	0005	0010	0000	0252
NNW	0005	0005	0010	0015	0024	0000	0039	0010	0029	0000	0000	0000	0000	0039
TOTAL	0015	0102	0116	0348	0319	0218	0885	0145	0324	0469	0198	0053	0015	1205

DIRECTION	STABILITY CATEGORY D							STABILITY CATEGORY E			STABILITY CATEGORY F			SUMMER WIND DIRECTION DISTRIBUTION
	WIND SPEED (M/SEC)							WIND SPEED (M/SEC)			WIND SPEED (M/SEC)			
(SECTOR)	0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.6	>10.8	TOTAL	1.6-3.0	3.1-5.1	TOTAL	0-1.5	1.6-3.0	TOTAL	
N	0005	0019	0000	0000	0000	0000	0024	0000	0000	0000	0000	0000	0000	0102
NNE	0000	0015	0000	0000	0000	0000	0015	0005	0000	0005	0005	0005	0010	0097
NE	0005	0024	0015	0005	0000	0000	0048	0005	0000	0005	0000	0005	0005	0194
ENE	0010	0024	0039	0005	0000	0000	0077	0015	0000	0015	0010	0000	0010	0194
E	0015	0073	0029	0000	0000	0000	0116	0019	0000	0019	0015	0019	0034	0300
ESE	0005	0039	0000	0000	0000	0000	0044	0010	0000	0010	0010	0005	0015	0232
SE	0005	0019	0015	0000	0000	0000	0039	0015	0000	0015	0015	0010	0024	0169
SSE	0010	0015	0005	0000	0000	0000	0029	0039	0005	0044	0034	0029	0063	0174
S	0005	0034	0005	0000	0000	0000	0044	0029	0000	0029	0029	0049	0077	0174
SSW	0000	0034	0010	0005	0000	0000	0048	0034	0005	0039	0024	0063	0087	0198
SW	0015	0024	0058	0019	0000	0000	0116	0044	0029	0073	0024	0082	0106	0310
WSW	0015	0032	0213	0087	0019	0000	0426	0063	0097	0160	0010	0029	0039	0692
W	0024	0174	0721	1335	0634	0053	2941	0077	0387	0464	0019	0087	0106	3696
WNW	0010	0121	0358	1001	0421	0097	2008	0029	0059	0087	0010	0024	0034	2675
NW	0019	0077	0029	0019	0015	0015	0174	0005	0000	0005	0019	0000	0019	0658
NNW	0005	0024	0010	0000	0000	0000	0039	0000	0000	0000	0000	0010	0010	0135
TOTAL	0145	0808	1505	2477	1089	0164	6188	0387	0581	0968	0223	0416	0639	

TABLE B-4

FALL JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE EDIZ HOOK 10-METER TOWER

STABILITY CATEGORY A

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	TOTAL
N	0000	0000	0000
NNE	0000	0000	0000
NE	0000	0000	0000
ENE	0000	0000	0000
E	0000	0000	0000
ESE	0000	0000	0000
SE	0000	0000	0000
SSE	0000	0000	0000
S	0000	0000	0000
SSW	0000	0000	0000
SW	0000	0000	0000
WSW	0000	0000	0000
W	0000	0000	0000
WNW	0000	0000	0000
NW	0000	0000	0000
NNW	0000	0000	0000
TOTAL	0000	0000	0000

STABILITY CATEGORY B

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	TOTAL
N	0015	0005	0000	0020
NNE	0000	0010	0000	0010
NE	0025	0010	0000	0035
ENE	0040	0020	0000	0060
E	0030	0040	0005	0075
ESE	0035	0050	0000	0085
SE	0015	0005	0000	0020
SSE	0030	0000	0000	0030
S	0015	0000	0000	0015
SSW	0000	0000	0000	0000
SW	0005	0000	0000	0005
WSW	0010	0005	0000	0015
W	0000	0000	0000	0000
WNW	0005	0000	0000	0005
NW	0010	0000	0000	0010
NNW	0000	0005	0000	0005
TOTAL	0236	0151	0005	0392

STABILITY CATEGORY C

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8	TOTAL
N	0050	0010	0000	0000	0000	0000	0060
NNE	0010	0010	0010	0000	0000	0000	0030
NE	0005	0075	0020	0000	0000	0000	0100
ENE	0035	0090	0030	0000	0000	0000	0156
E	0035	0131	0020	0000	0000	0000	0186
ESE	0005	0075	0010	0000	0000	0000	0090
SE	0020	0055	0000	0000	0000	0000	0075
SSE	0005	0020	0005	0000	0000	0000	0030
S	0035	0005	0000	0000	0000	0000	0040
SSW	0005	0005	0000	0000	0000	0000	0010
SW	0010	0015	0000	0000	0000	0000	0025
WSW	0005	0010	0000	0000	0000	0000	0015
W	0010	0015	0025	0000	0000	0000	0050
WNW	0015	0030	0035	0005	0000	0000	0085
NW	0020	0030	0010	0000	0000	0000	0060
NNW	0015	0010	0000	0000	0000	0000	0025
TOTAL	0281	0588	0166	0005	0000	0000	1040

STABILITY CATEGORY D

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	3.1-5.1	5.2-8.2	8.3-10.8	>10.8	TOTAL
N	0020	0050	0025	0005	0005	0000	0105
NNE	0010	0095	0050	0030	0000	0000	0176
NE	0020	0095	0025	0075	0045	0000	0261
ENE	0030	0171	0040	0005	0005	0000	0251
E	0050	0246	0075	0010	0000	0000	0382
ESE	0070	0151	0045	0005	0000	0000	0271
SE	0070	0116	0035	0005	0000	0000	0226
SSE	0075	0121	0050	0000	0000	0000	0246
S	0060	0131	0010	0000	0000	0000	0201
SSW	0040	0131	0005	0000	0000	0000	0176
SW	0060	0131	0045	0010	0000	0000	0246
WSW	0095	0151	0085	0045	0005	0000	0382
W	0075	0211	0241	0331	0055	0035	0949
WNW	0035	0181	0156	0166	0080	0025	0643
NW	0045	0191	0035	0045	0075	0005	0397
NNW	0035	0090	0015	0000	0000	0000	0141
TOTAL	0794	2250	0939	0733	0271	0065	5053

STABILITY CATEGORY E

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 1.6-3.0	3.1-5.1	TOTAL
N	0000	0015	0015
NNE	0005	0000	0005
NE	0000	0000	0000
ENE	0010	0000	0010
E	0075	0005	0080
ESE	0030	0000	0030
SE	0050	0005	0055
SSE	0070	0030	0100
S	0121	0040	0161
SSW	0126	0015	0141
SW	0141	0095	0236
WSW	0100	0030	0131
W	0121	0065	0186
WNW	0080	0010	0090
NW	0020	0000	0020
NNW	0005	0000	0005
TOTAL	0954	0311	1266

STABILITY CATEGORY F

DIRECTION (SECTOR)	WIND SPEED (M/SEC) 0-1.5	1.6-3.0	TOTAL
N	0005	0005	0010
NNE	0010	0010	0020
NE	0015	0020	0035
ENE	0010	0005	0015
E	0045	0045	0090
ESE	0060	0090	0151
SE	0060	0050	0110
SSE	0090	0131	0221
S	0221	0246	0467
SSW	0121	0266	0387
SW	0110	0246	0357
WSW	0065	0065	0131
W	0070	0085	0156
WNW	0020	0035	0055
NW	0015	0010	0025
NNW	0015	0005	0020
TOTAL	0934	1316	2250

DIRECTION (SECTOR)	FALL WIND DIRECTION DISTRIBUTION
N	0211
NNE	0241
NE	0432
ENE	0492
E	0814
ESE	0628
SE	0487
SSE	0628
S	0884
SSW	0713
SW	0869
WSW	0673
W	1341
WNW	0879
NW	0512
NNW	0196

TABLE B-5

ANNUAL JOINT FREQUENCY OF OCCURRENCE OF WIND-SPEED AND WIND-DIRECTION CATEGORIES, CLASSIFIED ACCORDING TO THE PASQUILL STABILITY CATEGORIES, AT THE EDIZ HOOK 10-METER TOWER

DIRECTION (SECTOR)	STABILITY CATEGORY A WIND SPEED (M/SEC) 0-1.5	 1.6-3.0	 TOTAL	STABILITY CATEGORY B WIND SPEED (M/SEC) 0-1.5	 1.6-3.0	 3.1-5.1	 TOTAL	STABILITY CATEGORY C WIND SPEED (M/SEC) 0-1.5	 1.6-3.0	 3.1-5.1	 5.2-8.2	 8.3-10.8	 >10.8	 TOTAL
N	0000	0001	0001	0012	0007	0001	0020	0018	0014	0004	0000	0000	0000	0036
NNE	0000	0000	0000	0016	0012	0001	0029	0008	0010	0008	0000	0000	0000	0026
NE	0000	0001	0001	0017	0029	0007	0053	0011	0053	0024	0000	0000	0000	0088
ENE	0001	0005	0005	0024	0037	0001	0058	0011	0045	0036	0000	0000	0000	0091
E	0001	0006	0007	0025	0059	0001	0085	0016	0061	0026	0000	0000	0000	0103
ESE	0001	0006	0007	0028	0043	0004	0075	0011	0049	0014	0000	0000	0000	0075
SE	0001	0006	0007	0018	0017	0001	0036	0011	0037	0006	0000	0000	0000	0054
SSE	0000	0001	0001	0018	0005	0000	0023	0010	0012	0002	0000	0000	0000	0024
S	0000	0001	0001	0016	0000	0000	0016	0024	0008	0001	0000	0000	0000	0034
SSW	0000	0000	0000	0005	0001	0000	0006	0008	0002	0000	0000	0000	0000	0011
SW	0000	0000	0000	0002	0002	0000	0005	0012	0005	0001	0000	0000	0000	0018
WSW	0000	0001	0001	0007	0001	0002	0011	0005	0006	0004	0002	0000	0000	0017
W	0000	0000	0000	0005	0001	0004	0010	0011	0022	0041	0004	0002	0000	0079
WNW	0000	0001	0001	0007	0016	0020	0043	0007	0025	0083	0055	0008	0004	0183
NW	0000	0002	0002	0008	0030	0040	0078	0008	0048	0052	0001	0002	0000	0112
NNW	0001	0001	0002	0005	0019	0004	0028	0014	0023	0001	0000	0000	0000	0039
TOTAL	0005	0032	0037	0213	0278	0087	0575	0185	0421	0304	0063	0013	0004	0996

DIRECTION (SECTOR)	STABILITY CATEGORY D WIND SPEED (M/SEC) 0-1.5	 1.6-3.0	 3.1-5.1	 5.2-8.2	 8.3-10.8	 >10.8	 TOTAL	STABILITY CATEGORY E WIND SPEED (M/SEC) 1.6-3.0	 3.1-5.1	 TOTAL	STABILITY CATEGORY F WIND SPEED (M/SEC) 0-1.5	 1.6-3.0	 TOTAL	ANNUAL WIND DIRECTION DISTRIBUTION
N	0008	0012	0019	0022	0005	0000	0067	0001	0007	0008	0005	0005	0010	0162
NNE	0008	0043	0039	0023	0000	0000	0113	0005	0016	0020	0004	0006	0010	0199
NE	0017	0072	0036	0037	0016	0000	0178	0008	0019	0026	0005	0014	0019	0366
ENE	0018	0089	0045	0020	0001	0000	0173	0016	0016	0031	0006	0007	0013	0372
E	0030	0153	0064	0013	0002	0002	0265	0037	0010	0047	0018	0024	0042	0556
ESE	0023	0102	0042	0014	0001	0001	0184	0025	0018	0043	0022	0034	0055	0439
SE	0036	0085	0054	0006	0000	0000	0182	0045	0026	0071	0029	0030	0059	0409
SSE	0054	0091	0035	0006	0000	0000	0187	0063	0064	0126	0052	0105	0156	0516
S	0053	0106	0014	0000	0000	0000	0173	0095	0036	0131	0091	0197	0289	0644
SSW	0028	0105	0018	0001	0001	0000	0153	0094	0022	0116	0071	0174	0245	0531
SW	0046	0150	0091	0019	0001	0000	0308	0136	0067	0203	0058	0237	0296	0824
WSW	0047	0136	0154	0082	0024	0011	0454	0067	0064	0131	0029	0052	0081	0694
W	0043	0168	0442	0750	0279	0036	1718	0077	0191	0268	0031	0069	0100	2176
WNW	0017	0123	0230	0469	0220	0055	1114	0040	0034	0073	0014	0023	0037	1452
NW	0018	0122	0047	0037	0030	0010	0264	0011	0002	0013	0013	0007	0020	0490
NNW	0014	0057	0008	0006	0002	0000	0088	0002	0004	0006	0005	0009	0013	0176
TOTAL	0461	1627	1338	1515	0584	0116	5640	0722	0594	1316	0452	0989	1440	

TABLE B-6. THE HOURLY METEOROLOGICAL INPUTS FOR THE 24-HOUR PERIODS CONSIDERED IN THE ATTAINMENT STATUS CALCULATIONS.

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	PGT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				21 AUGUST 1978					
1	320	1.00	137	285	.003	F	.10	.0235	.0336
2	295	1.10	137	285	.003	F	.10	.0235	.0336
3	235	1.30	121	285	.003	F	.10	.0235	.0336
4	295	2.00	115	285	.003	E	.10	.0350	.0501
5	MISSING - NOT INCLUDED IN AVERAGES								
6	270	2.20	107	285	.003	E	.10	.0350	.0501
7	280	1.60	107	285	.003	D	.10	.0465	.0665
8	305	2.20	202	285	.003	D	.10	.0465	.0665
9	305	3.10	244	285	.003	C	.10	.0735	.1051
10	310	2.20	244	285	.003	C	.10	.0735	.1051
11	310	2.20	286	285	.003	B	.10	.1080	.1544
12	305	1.80	286	286	.003	B	.10	.1080	.1544
13	305	2.70	286	286	.003	C	.10	.0735	.1208
14	305	2.90	322	286	.003	C	.10	.0735	.1208
15	300	4.90	322	286	.003	C	.10	.0735	.1051
16	300	5.60	163	286	.003	D	.10	.0465	.0764
17	300	6.70	145	286	.003	D	.10	.0465	.0764
18	295	7.20	145	285	.003	D	.10	.0465	.0764
19	295	6.90	163	285	.003	D	.10	.0465	.0764
20	285	6.50	235	285	.003	D	.10	.0465	.0764
21	285	7.40	279	285	.003	D	.10	.0465	.0764
22	295	7.40	349	285	.003	D	.10	.0465	.0665
23	290	7.40	365	285	.003	D	.10	.0465	.0665
24	285	7.80	407	285	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				10 NOVEMBER 1978					
1	40	9.20	211	276	.003	D	.10	.0465	.0665
2	45	8.90	183	277	.003	D	.10	.0465	.0665
3	40	9.40	157	277	.003	D	.10	.0465	.0665
4	45	8.00	145	277	.003	D	.10	.0465	.0665
5	30	7.60	151	277	.003	D	.10	.0465	.0665
6	40	8.00	157	277	.003	D	.10	.0465	.0665
7	30	7.80	163	277	.003	D	.10	.0465	.0665
8	35	7.80	229	277	.003	D	.10	.0465	.0665
9	40	8.70	301	277	.003	D	.10	.0465	.0929
10	40	7.60	383	277	.003	D	.10	.0465	.0929
11	40	8.00	383	277	.003	D	.10	.0465	.0829
12	55	7.80	377	277	.003	D	.10	.0465	.0665
13	50	8.00	343	278	.003	D	.10	.0465	.0665
14	60	6.00	289	278	.003	D	.10	.0465	.0764
15	60	2.70	203	278	.003	D	.10	.0465	.0764
16	300	1.30	155	278	.003	F	.10	.0235	.0336
17	50	6.30	143	278	.003	D	.10	.0465	.0764
18	50	8.50	191	278	.003	D	.10	.0465	.0764
19	55	9.80	203	278	.003	D	.10	.0465	.0665
20	90	8.00	235	277	.003	D	.10	.0465	.0665
21	200	2.90	235	277	.003	F	.10	.0235	.0409
22	200	2.50	245	275	.003	F	.10	.0235	.0409
23	180	2.00	231	275	.003	F	.10	.0235	.0336
24	170	2.70	225	275	.003	F	.10	.0235	.0336

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				24 MARCH 1979					
1	285	6.90	155	281	.003	D	.10	.0465	.0665
2	295	7.80	223	281	.003	D	.10	.0465	.0665
3	300	8.50	211	281	.003	D	.10	.0465	.0764
4	300	8.90	157	281	.003	D	.10	.0465	.0764
5	290	9.20	83	281	.003	D	.10	.0465	.0665
6	300	8.00	93	281	.003	D	.10	.0465	.0665
7	280	5.80	135	281	.003	D	.10	.0465	.0665
8	290	7.20	230	281	.003	D	.10	.0465	.0665
9	295	7.60	412	281	.003	D	.10	.0465	.0829
10	295	6.90	440	282	.003	D	.10	.0465	.0829
11	295	7.60	540	282	.003	D	.10	.0465	.0829
12	285	7.60	582	283	.003	D	.10	.0465	.0878
13	285	9.80	582	283	.003	D	.10	.0465	.0878
14	285	10.30	601	283	.003	D	.10	.0465	.0878
15	285	9.60	586	283	.003	D	.10	.0465	.0878
16	275	8.30	586	282	.003	D	.10	.0465	.0665
17	270	7.40	586	282	.003	D	.10	.0465	.0665
18	275	8.30	586	281	.003	D	.10	.0465	.0665
19	270	6.50	586	281	.003	D	.10	.0465	.0665
20	265	5.80	586	281	.003	D	.10	.0465	.0665
21	270	5.80	586	281	.003	D	.10	.0465	.0665
22	265	6.30	586	280	.003	D	.10	.0465	.0665
23	235	5.40	271	280	.003	D	.10	.0465	.0665
24	230	5.40	239	280	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	PGT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				6 APRIL 1979					
1	270	6.00	299	281	.003	D	.10	.0465	.0764
2	270	6.30	289	281	.003	D	.10	.0465	.0764
3	275	6.30	267	281	.003	D	.10	.0465	.0665
4	270	6.90	263	281	.003	D	.10	.0465	.0665
5	275	6.70	223	281	.003	D	.10	.0465	.0665
6	270	6.30	175	281	.003	D	.10	.0465	.0665
7	250	6.00	149	281	.003	D	.10	.0465	.0665
8	270	5.10	448	281	.003	D	.10	.0465	.0665
9	300	4.50	860	281	.003	D	.10	.0465	.0665
10	295	7.60	962	282	.003	D	.10	.0465	.0665
11	285	8.90	1080	283	.003	D	.10	.0465	.0665
12	290	9.60	475	283	.003	D	.10	.0465	.0829
13	290	8.90	511	283	.003	D	.10	.0465	.0829
14	290	8.90	533	283	.003	D	.10	.0465	.0829
15	300	9.80	537	283	.003	D	.10	.0465	.0665
16	295	10.10	523	282	.003	D	.10	.0465	.0829
17	295	11.60	517	282	.003	D	.10	.0465	.0829
18	295	11.20	457	281	.003	D	.10	.0465	.0829
19	285	9.60	385	281	.003	D	.10	.0465	.0665
20	280	9.20	305	281	.003	D	.10	.0465	.0665
21	275	8.50	251	281	.003	D	.10	.0465	.0665
22	265	6.30	223	280	.003	D	.10	.0465	.0665
23	255	7.40	223	280	.003	D	.10	.0465	.0665
24	250	6.30	237	279	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				29 APRIL 1979					
1	270	4.90	247	284	.003	E	.10	.0350	.0575
2	270	4.50	255	284	.003	E	.10	.0350	.0575
3	280	5.80	249	284	.003	D	.10	.0465	.0665
4	270	4.20	245	284	.003	E	.10	.0350	.0591
5	270	4.20	237	284	.003	D	.10	.0465	.0764
6	270	4.90	253	283	.003	D	.10	.0465	.0764
7	280	5.40	332	284	.003	D	.10	.0465	.0665
8	275	6.30	496	285	.003	D	.10	.0465	.0665
9	280	6.30	496	285	.003	D	.10	.0465	.0764
10	280	6.30	642	285	.003	D	.10	.0465	.0764
11	285	5.40	642	285	.003	D	.10	.0465	.0665
12	280	5.40	642	285	.003	D	.10	.0465	.0764
13	280	6.30	694	285	.003	D	.10	.0465	.0764
14	285	6.70	756	286	.003	D	.10	.0465	.0665
15	290	8.00	756	285	.003	D	.10	.0465	.0665
16	285	8.00	331	285	.003	D	.10	.0465	.0764
17	285	8.30	337	285	.003	D	.10	.0465	.0764
18	290	8.50	321	284	.003	D	.10	.0465	.0829
19	280	8.30	295	284	.003	D	.10	.0465	.0829
20	280	8.30	275	283	.003	D	.10	.0465	.0829
21	275	7.60	275	283	.003	D	.10	.0465	.0665
22	280	8.30	275	283	.003	D	.10	.0465	.0764
23	280	7.60	283	283	.003	D	.10	.0465	.0764
24	275	7.80	293	283	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				26 MAY 1979					
1	250	4.00	261	285	.003	E	.10	.0350	.0501
2	270	3.40	285	285	.003	D	.10	.0465	.0764
3	270	5.80	329	285	.003	D	.10	.0465	.0764
4	295	7.40	385	285	.003	D	.10	.0465	.0665
5	290	7.60	355	285	.003	D	.10	.0465	.0764
6	290	3.60	420	285	.003	D	.10	.0465	.0764
7	300	4.50	702	286	.003	D	.10	.0465	.0665
8	295	4.20	1020	286	.003	D	.10	.0465	.0665
9	295	3.10	1080	285	.003	B	.10	.1080	.1544
10	305	7.20	1080	283	.003	D	.10	.0465	.0665
11	280	11.20	1080	284	.003	D	.10	.0465	.0665
12	295	11.80	1154	285	.003	D	.10	.0465	.0665
13	300	12.50	1520	285	.003	D	.10	.0465	.0665
14	305	13.40	1920	285	.003	D	.10	.0465	.0764
15	305	13.20	2190	285	.003	D	.10	.0465	.0764
16	300	12.50	2190	285	.003	D	.10	.0465	.0665
17	305	11.60	2190	285	.003	D	.10	.0465	.0665
18	300	8.70	2190	284	.003	D	.10	.0465	.0665
19	295	8.70	2190	284	.003	D	.10	.0465	.0665
20	290	7.40	2190	283	.003	D	.10	.0465	.0665
21	280	7.40	361	282	.003	D	.10	.0465	.0764
22	280	5.60	321	283	.003	D	.10	.0465	.0764
23	275	6.70	321	283	.003	D	.10	.0465	.0764
24	275	6.90	349	282	.003	D	.10	.0465	.0764

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
3 JUNE 1979									
1	275	8.30	325	286	.003	D	.10	.0465	.0665
2	280	8.70	317	286	.003	D	.10	.0465	.0829
3	280	9.40	279	286	.003	D	.10	.0465	.0829
4	280	8.70	289	286	.003	D	.10	.0465	.0929
5	275	9.20	243	286	.003	D	.10	.0465	.0665
6	280	9.40	262	286	.003	D	.10	.0465	.0665
7	285	8.00	324	286	.003	D	.10	.0465	.0665
8	280	7.20	372	286	.003	D	.10	.0465	.0665
9	295	7.20	616	286	.003	D	.10	.0465	.0764
10	295	7.60	616	286	.003	D	.10	.0465	.0764
11	285	7.40	686	288	.003	C	.10	.0735	.1208
12	285	7.60	860	288	.003	C	.10	.0735	.1208
13	280	8.70	902	298	.003	C	.10	.0735	.1051
14	260	10.10	902	286	.003	D	.10	.0465	.0764
15	280	10.70	902	286	.003	D	.10	.0465	.0764
16	275	9.60	902	286	.003	D	.10	.0465	.0764
17	275	9.40	553	286	.003	D	.10	.0465	.0764
18	270	8.50	463	286	.003	D	.10	.0465	.0665
19	275	7.20	409	286	.003	D	.10	.0465	.0829
20	275	7.20	409	286	.003	D	.10	.0465	.0929
21	275	7.80	419	286	.003	D	.10	.0465	.0829
22	270	8.30	385	286	.003	D	.10	.0465	.0665
23	275	7.20	337	286	.003	D	.10	.0465	.0665
24	280	5.10	295	286	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
8 JUNE 1979									
1	285	5.80	291	284	.003	D	.10	.0465	.0665
2	275	5.10	273	284	.003	E	.10	.0350	.0501
3	270	4.20	241	283	.003	E	.10	.0350	.0501
4	260	3.10	197	283	.003	E	.10	.0350	.0501
5	260	2.70	177	282	.003	F	.10	.0235	.0336
6	270	2.50	177	283	.003	D	.10	.0465	.0665
7	260	3.10	272	284	.003	D	.10	.0465	.0665
8	310	2.90	488	285	.003	C	.10	.0735	.1051
9	310	3.60	540	284	.003	B	.10	.1080	.1544
10	305	3.80	540	285	.003	C	.10	.0735	.1051
11	310	3.10	638	285	.003	B	.10	.1080	.1775
12	310	3.60	638	285	.003	B	.10	.1080	.1775
13	305	3.80	660	286	.003	B	.10	.1080	.1544
14	305	4.00	824	286	.003	C	.10	.0735	.1051
15	295	5.10	834	286	.003	C	.10	.0735	.1208
16	295	5.40	834	286	.003	C	.10	.0735	.1208
17	295	4.90	834	286	.003	D	.10	.0465	.0665
18	290	6.00	962	287	.003	D	.10	.0465	.0764
19	290	7.20	962	286	.003	D	.10	.0465	.0764
20	285	8.30	962	285	.003	D	.10	.0465	.0665
21	275	6.70	287	285	.003	D	.10	.0465	.0764
22	275	6.70	237	284	.003	D	.10	.0465	.0764
23	280	8.00	223	284	.003	D	.10	.0465	.0665
24	285	7.60	213	284	.003	D	.10	.0465	.0764

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				10 JUNE 1979					
1	280	8.30	229	284	.003	D	.10	.0465	.0665
2	285	8.00	269	284	.003	D	.10	.0465	.0665
3	290	7.60	269	284	.003	D	.10	.0465	.0665
4	280	7.20	323	284	.003	D	.10	.0465	.0829
5	280	6.00	327	284	.003	D	.10	.0465	.0829
6	280	6.90	528	285	.003	D	.10	.0465	.0829
7	285	8.00	586	285	.003	D	.10	.0465	.0665
8	295	8.70	660	285	.003	D	.10	.0465	.0829
9	295	8.00	660	285	.003	D	.10	.0465	.0829
10	295	8.00	704	286	.003	D	.10	.0465	.0829
11	290	8.00	746	286	.003	C	.10	.0735	.1310
12	290	8.50	752	286	.003	C	.10	.0735	.1310
13	290	9.40	1010	287	.003	C	.10	.0735	.1310
14	285	10.10	1010	287	.003	D	.10	.0465	.0764
15	285	10.10	1010	286	.003	D	.10	.0465	.0764
16	280	10.30	445	285	.003	D	.10	.0465	.0878
17	280	10.10	425	285	.003	D	.10	.0465	.0878
18	280	9.40	397	285	.003	D	.10	.0465	.0876
19	280	9.80	391	285	.003	D	.10	.0465	.0878
20	275	9.80	419	285	.003	D	.10	.0465	.0918
21	275	8.30	431	285	.003	D	10	.0465	.0918
22	275	8.90	459	284	.003	D	.10	.0465	.0918
23	275	8.30	473	284	.003	D	.10	.0465	.0916
24	275	8.70	487	284	.003	D	.10	.0465	.0918

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				26 JUNE 1979					
1	280	8.90	401	286	.003	D	.10	.0465	.0764
2	280	8.30	381	286	.003	D	.10	.0465	.0764
3	275	7.20	353	286	.003	D	.10	.0465	.0829
4	275	6.50	321	286	.003	D	.10	.0465	.0929
5	275	5.60	297	286	.003	D	.10	.0465	.0829
6	270	5.10	248	286	.003	D	.10	.0465	.0764
7	270	5.40	424	286	.003	D	.10	.0465	.0764
8	275	5.80	440	286	.003	D	.10	.0465	.0665
9	295	5.80	456	286	.003	D	.10	.0465	.0764
10	295	6.00	494	286	.003	D	.10	.0465	.0764
11	290	6.70	504	288	.003	C	.10	.0735	.1208
12	290	7.60	604	288	.003	C	.10	.0735	.1208
13	285	8.90	678	288	.003	C	.10	.0735	.1051
14	285	9.60	714	286	.003	D	.10	.0465	.0764
15	285	10.50	714	288	.003	D	.10	.0465	.0764
16	275	10.30	714	287	.003	D	.10	.0465	.1009
17	275	10.70	714	286	.003	D	.10	.0465	.1009
18	275	11.80	509	286	.003	D	.10	.0465	.1009
19	275	10.50	487	285	.003	D	.10	.0465	.1009
20	275	9.80	443	285	.003	D	.10	.0465	.1009
21	275	11.00	403	285	.003	D	.10	.0465	.1009
22	275	10.70	391	285	.003	D	.10	.0465	.1009
23	275	10.50	397	284	.003	D	.10	.0465	.1009
24	280	11.60	397	284	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				28 JUNE 1979					
1	265	4.90	273	283	.003	D	.10	.0465	.0665
2	270	5.40	239	283	.003	D	.10	.0465	.0665
3	280	6.00	209	283	.003	D	.10	.0465	.0665
4	270	4.70	181	282	.003	D	.10	.0465	.0764
5	270	2.90	205	282	.003	D	.10	.0465	.0764
6	280	4.00	235	281	.003	D	.10	.0465	.0665
7	275	5.10	338	282	.003	D	.10	.0465	.0665
8	280	5.60	404	282	.003	D	.10	.0465	.0918
9	280	6.00	410	283	.003	D	.10	.0465	.0918
10	280	5.80	458	284	.003	D	.10	.0465	.0918
11	280	6.50	458	285	.003	D	.10	.0465	.0918
12	280	8.30	508	285	.003	D	.10	.0465	.0918
13	285	10.10	594	286	.003	C	.10	.0735	.1051
14	280	10.10	618	287	.003	D	.10	.0465	.0878
15	280	9.80	626	287	.003	D	.10	.0465	.0878
16	280	9.80	626	287	.003	D	.10	.0465	.0878
17	280	11.00	626	286	.003	D	.10	.0465	.0878
18	275	11.20	626	286	.003	D	.10	.0465	.0952
19	275	9.80	626	285	.003	D	.10	.0465	.0952
20	275	11.20	415	285	.003	D	.10	.0465	.0952
21	275	9.80	361	285	.003	D	.10	.0465	.0952
22	275	9.20	371	235	.003	D	.10	.0465	.0952
23	275	9.20	359	285	.003	D	.10	.0465	.0952
24	270	7.80	353	284	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				19 JULY 1979					
1	275	7.80	241	285	.003	D	.10	.0465	.0878
2	275	6.30	237	285	.003	D	.10	.0465	.0878
3	275	3.60	231	285	.003	D	.10	.0465	.0878
4	275	3.40	205	285	.003	D	.10	.0465	.0878
5	280	2.90	201	285	.003	D	.10	.0465	.0665
6	275	3.10	199	285	.003	D	.10	.0465	.0665
7	275	3.10	336	285	.003	C	.10	.0735	.1051
8	310	2.70	398	285	.003	C	.10	.0735	.1051
9	305	4.50	416	286	.003	C	.10	.0735	.1208
10	305	4.00	462	287	.003	C	.10	.0735	.1208
11	310	3.60	462	288	.003	B	.10	.1080	.1544
12	305	3.60	462	288	.003	B	.10	.1080	.1544
13	300	5.40	518	299	.003	C	.10	.0735	.1051
14	295	5.40	536	289	.003	C	.10	.0735	.1051
15	305	6.50	536	288	.003	D	.10	.0465	.0665
16	300	6.90	536	288	.003	D	.10	.0465	.0764
17	300	7.40	536	288	.003	D	.10	.0465	.0764
18	290	6.30	536	298	.003	D	.10	.0465	.0665
19	295	6.70	127	287	.003	D	.10	.0465	.0764
20	295	8.50	171	286	.003	D	.10	.0465	.0764
21	300	7.40	241	286	.003	D	.10	.0465	.0665
22	290	8.00	287	286	.003	D	.10	.0465	.0665
23	280	5.40	259	286	.003	D	.10	.0465	.0665
24	275	3.80	227	286	.003	E	.10	.0350	.0501

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				21 JULY 1979					
1	280	8.90	437	286	.003	D	.10	.0465	.0829
2	280	8.90	391	285	.003	D	.10	.0465	.0829
3	280	7.60	309	285	.003	D	.10	.0465	.0829
4	275	5.80	223	285	.003	D	.10	.0465	.0665
5	270	6.70	207	285	.003	D	.10	.0465	.0665
6	280	5.80	231	285	.003	D	.10	.0465	.0665
7	285	6.30	434	285	.003	D	.10	.0465	.0665
8	295	5.40	540	285	.003	D	.10	.0465	.0764
9	295	4.50	914	286	.003	D	.10	.0465	.0764
10	300	4.90	914	287	.003	D	.10	.0465	.0665
11	290	4.50	984	287	.003	C	.10	.0735	.1051
12	295	4.70	1080	289	.003	C	.10	.0735	.1051
13	290	6.30	1080	289	.003	C	.10	.0735	.1051
14	290	8.50	1100	289	.003	D	.10	.0465	.0665
15	295	8.90	1100	289	.003	D	.10	.0465	.0665
16	290	8.30	1100	289	.003	D	.10	.0465	.0764
17	290	9.40	421	288	.003	D	.10	.0465	.0764
19	285	7.40	443	288	.003	D	.10	.0465	.0829
19	285	9.80	437	287	.003	D	.10	.0465	.0829
20	265	8.90	391	287	.003	D	.10	.0465	.0829
21	280	6.50	305	286	.003	D	.10	.0465	.0665
22	280	4.70	257	285	.003	E	.10	.0350	.0501
23	285	6.00	239	285	.003	D	.10	.0465	.0764
24	285	6.30	269	286	.003	D	.10	.0465	.0764

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
22 JULY 1979									
1	265	5.80	253	285	.003	D	.10	.0465	.0665
2	280	4.70	225	285	.003	E	.10	.0350	.0501
3	270	5.40	179	285	.003	D	.10	.0465	.0665
4	280	3.80	173	285	.003	E	.10	.0350	.0501
5	270	4.00	153	285	.003	E	.10	.0350	.0501
6	255	3.60	179	285	.003	D	.10	.0465	.0665
7	270	2.90	153	285	.003	C	.10	.0735	.1051
8	305	3.80	680	286	.003	C	.10	.0735	.1051
9	310	3.10	712	286	.003	B	.10	.1080	.1544
10	310	4.50	712	287	.003	C	.10	.0735	.1051
11	305	4.70	772	288	.003	C	.10	.0735	.1208
12	305	4.90	812	288	.003	C	.10	.0735	.1208
13	305	4.50	812	289	.003	B	.10	.1080	.1544
14	305	4.50	940	289	.003	C	.10	.0735	.1051
15	295	4.90	940	289	.003	C	.10	.0735	.1051
16	295	6.70	840	288	.003	D	.10	.0465	.0665
17	290	8.70	846	288	.003	D	.10	.0465	.0764
18	290	9.60	946	288	.003	D	.10	.0465	.0764
19	285	10.10	946	287	.003	D	.10	.0465	.0665
20	280	9.20	846	286	.003	D	.10	.0465	.0829
21	290	6.70	299	286	.003	D	.10	.0465	.0929
22	280	5.40	265	286	.003	D	.10	.0465	.0829
23	275	6.50	251	286	.003	D	.10	.0465	.0764
24	290	7.40	257	285	.003	D	.10	.0465	.0764

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				24 JULY 1979					
1	285	5.40	223	283	.003	D	.10	.0465	.0665
2	280	4.50	219	283	.003	D	.10	.0465	.0665
3	275	4.90	215	283	.003	D	.10	.0465	.0764
4	275	4.90	235	283	.003	D	.10	.0465	.0764
5	280	4.00	225	283	.003	D	.10	.0465	.0764
6	280	3.60	209	283	.003	D	.10	.0465	.0764
7	270	2.90	388	283	.003	D	.10	.0465	.0665
8	290	3.80	412	284	.003	D	.10	.0465	.0665
9	300	4.00	414	285	.003	D	.10	.0465	.0665
10	300	4.00	448	285	.003	C	.10	.0735	.1051
11	305	4.20	512	285	.003	C	.10	.0735	.1051
12	310	4.70	546	285	.003	C	.10	.0735	.1051
13	300	5.40	548	286	.003	C	.10	.0735	.1051
14	290	5.40	624	288	.003	C	.10	.0735	.1051
15	300	5.80	712	287	.003	D	.10	.0465	.0665
16	305	6.50	712	287	.003	D	.10	.0465	.0665
17	300	8.00	712	280	.003	D	.10	.0465	.0665
18	290	8.30	716	287	.003	D	.10	.0465	.0665
19	295	8.90	716	296	.003	D	.10	.0465	.0764
20	295	8.70	173	286	.003	D	.10	.0465	.0764
21	290	6.90	225	285	.003	D	.10	.0465	.0665
22	285	6.30	281	285	.003	D	.10	.0465	.0665
23	280	6.90	261	284	.003	D	.10	.0465	.0665
24	285	9.20	245	284	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				25 JULY 1979					
1	290	7.80	175	284	.003	D	.10	.0465	.0665
2	285	7.80	175	283	.003	D	.10	.0465	.0665
3	280	6.00	175	284	.003	D	.10	.0465	.0665
4	275	5.80	163	284	.003	D	.10	.0465	.0665
5	280	5.80	157	283	.003	D	.10	.0465	.0829
6	280	5.80	181	283	.003	D	.10	.0465	.0829
7	280	4.50	173	283	.003	D	.10	.0465	.0829
8	285	5.80	173	284	.003	D	.10	.0465	.0665
9	300	4.50	428	285	.003	D	.10	.0465	.0665
10	305	4.50	472	285	.003	D	.10	.0465	.0665
11	300	4.90	498	286	.003	D	.10	.0465	.0665
12	300	5.40	558	285	.003	C	.10	.0735	.1208
13	300	5.40	584	286	.003	C	.10	.0735	.1208
14	290	6.30	618	286	.003	D	.10	.0465	.0829
15	290	7.20	648	286	.003	D	.10	.0465	.0829
16	290	7.80	652	286	.003	D	.10	.0465	.0829
17	295	7.80	658	286	.003	D	.10	.0465	.0665
19	290	8.30	656	286	.003	D	.10	.0465	.0764
19	290	9.80	656	286	.003	D	.10	.0465	.0764
20	285	8.90	259	285	.003	D	.10	.0465	.0665
21	290	8.90	329	284	.003	D	.10	.0465	.0665
22	285	8.70	267	285	.003	D	.10	.0465	.0665
23	280	6.50	249	284	.003	D	.10	.0465	.0665
24	275	6.50	233	284	.003	D	.10	.0465	.0665

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				2 AUGUST 1979					
1	275	6.00	227	286	.003	D	.10	.0465	.0665
2	265	4.90	209	286	.003	E	.10	.0350	.0501
3	260	4.50	185	286	.003	E	.10	.0350	.0501
4	260	4.50	173	285	.003	D	.10	.0465	.0665
5	270	3.60	171	285	.003	E	.10	.0350	.0501
6	285	3.60	171	285	.003	D	.10	.0465	.0665
7	310	4.20	640	286	.003	C	.10	.0735	.1051
8	305	4.20	768	286	.003	C	.10	.0735	.1208
9	305	4.50	790	287	.003	C	.10	.0735	.1208
10	310	4.20	798	287	.003	C	.10	.0735	.1208
11	310	4.90	830	287	.003	C	.10	.0735	.1208
12	305	4.50	860	288	.003	C	.10	.0735	.1051
13	300	4.90	990	289	.003	C	.10	.0735	.1208
14	300	5.60	890	289	.003	C	.10	.0735	.1208
15	300	6.50	892	289	.003	D	.10	.0465	.0665
16	295	6.30	998	289	.003	D	.10	.0465	.0665
17	290	7.60	930	288	.003	D	.10	.0465	.0665
18	295	7.40	960	288	.003	D	.10	.0465	.0665
19	290	9.40	960	288	.003	D	.10	.0465	.0665
20	280	8.00	960	286	.003	D	.10	.0465	.0665
21	290	7.40	337	286	.003	D	.10	.0465	.0665
22	280	6.30	325	286	.003	D	.10	.0465	.0829
23	280	6.00	287	286	.003	D	.10	.0465	.0829
24	280	6.00	253	285	.003	D	.10	.0465	.0829

TABLE B-6 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				8 AUGUST 1979					
1	280	5.80	237	285	.003	D	.10	.0465	.0665
2	280	5.10	197	285	.003	E	.10	.0350	.0501
3	285	6.50	175	285	.003	D	.10	.0465	.0665
4	270	5.60	149	285	.003	D	.10	.0465	.0665
5	265	5.40	141	285	.003	D	.10	.0465	.0665
6	260	4.90	137	285	.003	D	.10	.0465	.0665
7	265	4.50	137	285	.003	C	.10	.0735	.1051
8	280	3.40	886	288	.003	C	.10	.0735	.1051
9	310	4.20	902	288	.003	C	.10	.0735	.1051
10	310	3.60	902	288	.003	B	.10	.1080	.1775
11	310	3.60	902	288	.003	B	.10	.1080	.1775
12	310	3.80	902	289	.003	C	.10	.0735	.1051
13	310	3.10	902	288	.003	B	.10	.1080	.1544
14	305	5.10	902	289	.003	C	.10	.0735	.1051
15	290	7.40	902	289	.003	D	.10	.0465	.0665
16	295	7.20	902	288	.003	D	.10	.0465	.0665
17	290	7.20	928	288	.003	D	.10	.0465	.0665
18	285	7.20	928	287	.003	D	.10	.0465	.0929
19	285	8.50	928	286	.003	D	.10	.0465	.0929
20	285	8.30	133	286	.003	D	.10	.0465	.0829
21	280	6.90	89	285	.003	D	.10	.0465	.0878
22	280	5.40	47	285	.003	D	.10	.0465	.0878
23	280	5.40	55	285	.003	D	.10	.0465	.0878
24	280	5.60	55	285	.003	D	.10	.0465	.0878

TABLE B-7. THE HOURLY METEOROLOGICAL INPUTS FOR THE 3-HOUR PERIODS CONSIDERED IN THE ATTAINMENT STATUS CALCULATIONS.

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				23 AUGUST 1976					
16	290	2.50	454	288	.003	D	.10	.0465	.0829
17	290	2.20	454	288	.003	D	.10	.0465	.0829
18	290	1.80	454	287	.003	D	.10	.0465	.0829
				13 NOVEMBER 1978					
1	220	2.50	157	276	.003	F	.10	.0235	.0386
2	220	2.50	157	276	.003	F	.10	.0235	.0386
3	220	3.40	151	276	.003	E	.10	.0350	.0501
				12 DECEMBER 1978					
19	155	3.40	193	277	.003	E	.10	.0350	.0501
20	155	2.90	193	277	.003	F	.10	.0235	.0386
21	155	2.90	213	277	.003	F	.10	.0235	.0386
				19 DECEMBER 1978					
1	215	3.10	199	276	.003	D	.10	.0465	.0665
2	215	4.00	199	275	.003	E	.10	.0350	.0575
3	215	3.60	193	276	.003	E	.10	.0350	.0575
				20 DECEMBER 1978					
7	245	3.40	119	278	.003	D	.10	.0465	.0829
8	245	2.70	119	278	.003	D	.10	.0465	.0829
9	245	2.70	127	278	.003	D	.10	.0465	.0829

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				3 JANURAY 1979					
1	165	2.90	275	273	.003	F	.10	.0235	.0419
2	165	2.90	263	273	.003	F	.10	.0235	.0419
3	165	2.70	251	273	.003	F	.10	.0235	.0419
				5 JANUARY 1979					
22	170	3.80	263	274	.003	E	.10	.0350	.0575
23	170	3.60	275	274	.003	E	.10	.0350	.0575
24	170	2.90	279	273	.003	F	.10	.0235	.0336
				19 JANUARY 1979					
16	90	3.40	83	280	.003	D	.10	.0465	.0829
17	90	2.90	77	280	.003	D	.10	.0465	.0829
18	90	2.90	65	280	.003	D	.10	.0465	.0829
				27 JANUARY 1979					
1	270	4.90	1514	277	.003	D	.10	.0465	.0829
2	270	3.40	167	277	.003	D	.10	.0465	.0829
3	270	3.40	139	277	.003	D	.10	.0465	.0829
				1 MARCH 1979					
1	240	3.80	133	277	.003	D	.10	.0465	.0764
2	240	4.00	133	277	.003	D	.10	.0465	.0764
3	240	2.90	133	277	.003	E	.10	.0350	.0501

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				24 MARCH 1979					
13	285	7.60	582	283	.003	D	.10	.0465	.0829
14	285	9.80	582	283	.003	D	.10	.0465	.0829
15	285	10.30	601	283	.003	D	.10	.0465	.0829
				2 APRIL 1979					
4	270	4.00	223	280	.003	D	.10	.0465	.0829
5	270	3.80	203	280	.003	D	.10	.0465	.0829
6	270	3.10	169	280	.003	D	.10	.0465	.0829
				6 APRIL 1979					
16	295	10.10	523	282	.003	D	.10	.0465	.0829
17	295	11.60	517	282	.003	D	.10	.0465	.0829
18	295	11.20	457	281	.003	D	.10	.0465	.0929
				22 APRIL 1979					
10	125	2.00	336	285	.003	B	.10	.1080	.1925
11	125	2.20	380	286	.003	B	.10	.1080	.1925
12	125	1.80	942	287	.003	B	.10	.1080	.1925
				29 APRIL 1979					
4	270	4.20	245	284	.003	E	.10	.0350	.0501
5	270	4.20	237	284	.003	D	.10	.0465	.0764
6	270	4.90	253	283	.003	D	.10	.0465	.0764

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
1 MAY 1979									
7	280	4.20	243	283	.003	D	.10	.0465	.0829
8	280	4.50	412	283	.003	D	.10	.0465	.0829
9	280	4.00	412	283	.003	D	.10	.0465	.0829
7 MAY 1979									
10	50	2.70	906	284	.003	B	.10	.1080	.1925
11	50	2.50	906	284	.003	B	.10	.1080	.1925
12	50	2.00	906	284	.003	B	.10	.1080	.1925
3 JUNE 1979									
19	275	7.20	409	286	.003	D	.10	.0465	.0829
20	275	7.20	409	286	.003	D	.10	.0465	.0829
21	275	7.80	419	286	.003	D	.10	.0465	.0829
10 JUNE 1979									
4	280	7.20	323	284	.003	D	.10	.0465	.0829
5	280	6.00	327	284	.003	D	.10	.0465	.0829
6	280	6.90	528	285	.003	D	.10	.0465	.0829
10 JUNE 1979									
16	280	10.30	445	285	.003	D	.10	.0465	.0829
17	280	10.10	425	285	.003	D	.10	.0465	.0829
18	280	9.40	397	285	.003	D	.10	.0465	.0829

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				10 JUNE 1979					
22	275	8.90	459	284	.003	D	.10	.0465	.0829
23	275	8.30	473	284	.003	D	.10	.0465	.0929
24	275	8.70	487	284	.003	D	.10	.0465	.0829
				18 JUNE 1979					
4	270	4.50	207	285	.003	D	.10	.0465	.0829
5	270	4.20	201	285	.003	D	.10	.0465	.0829
6	270	3.40	900	285	.003	D	.10	.0465	.0829
				20 JUNE 1979					
4	245	4.50	271	285	.003	D	.10	.0465	.0829
5	245	4.50	243	285	.003	D	.10	.0465	.0829
6	245	4.50	235	285	.003	D	.10	.0465	.0829
				22 JUNE 1979					
10	285	3.60	1244	286	.003	D	.10	.0465	.0665
11	285	3.60	1324	287	.003	B	.10	.1080	.1775
12	285	3.60	1392	287	.003	B	.10	.1080	.1775
				26 JUNE 1979					
16	275	10.30	714	287	.003	D	.10	.0465	.0829
17	275	10.70	714	286	.003	D	.10	.0465	.0829
18	275	11.80	509	286	.003	D	.10	.0465	.0829

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				26 JUNE 1979					
19	275	10.50	487	285	.003	D	.10	.0465	.0829
20	275	9.80	443	285	.003	D	.10	.0465	.0829
21	275	11.00	403	285	.003	D	.10	.0465	.0829
				28 JUNE 1979					
10	280	5.80	458	284	.003	D	.10	.0465	.0829
11	280	6.50	458	285	.003	D	.10	.0465	.0829
12	280	8.30	508	285	.003	D	.10	.0465	.0829
				28 JUNE 1979					
19	275	9.80	626	285	.003	D	.10	.0465	.0829
20	275	11.20	415	285	.003	D	.10	.0465	.0829
21	275	9.80	361	285	.003	D	.10	.0465	.0829
				29 JUNE 1979					
7	260	4.20	906	285	.003	D	.10	.0465	.0829
8	260	4.00	1084	285	.003	D	.10	.0465	.0829
9	260	3.60	1140	285	.003	D	.10	.0465	.0829
				29 JUNE 1979					
10	265	3.60	1154	285	.003	D	.10	.0465	.0829
11	265	2.70	1312	286	.003	D	.10	.0465	.0829
12	265	3.10	1360	286	.003	D	.10	.0465	.0829

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				8 JULY 1979					
16	250	3.10	1460	289	.003	C	.10	.0735	.1051
17	250	4.00	1460	291	.003	D	.10	.0465	.0764
18	250	3.10	1460	291	.003	D	.10	.0465	.0764
				19 JULY 1979					
1	275	7.80	241	285	.003	D	.10	.0465	.0829
2	275	6.30	237	285	.003	D	.10	.0465	.0829
3	275	3.60	231	285	.003	D	.10	.0465	.0829
				21 JULY 1979					
1	280	8.90	437	286	.003	D	.10	.0465	.0829
2	280	8.90	391	286	.003	D	.10	.0465	.0829
3	280	7.60	309	286	.003	D	.10	.0465	.0829
				2 AUGUST 1979					
13	300	4.90	890	289	.003	C	.10	.0735	.1208
14	300	5.60	890	289	.003	C	.10	.0735	.1208
15	300	6.50	892	289	.003	D	.10	.0465	.0665
				2 AUGUST 1979					
22	280	6.30	325	286	.003	D	.10	.0465	.0829
23	280	6.00	287	286	.003	D	.10	.0465	.0829
24	280	6.00	253	285	.003	D	.10	.0465	.0829

TABLE B-7 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
8 AUGUST 1979									
10	310	3.60	902	288	.003	B	.10	.1080	.1775
11	310	3.60	902	288	.003	B	.10	.1080	.1775
12	310	3.80	902	289	.003	C	.10	.0735	.1051
8 AUGUST 1979									
22	280	5.40	47	285	.003	D	.10	.0465	.0829
23	280	5.40	55	285	.003	D	.10	.0465	.0829
24	280	5.60	55	285	.003	D	.10	.0465	.0929

TABLE B-8. THE HOURLY METEOROLOGICAL INPUTS FOR THE 24-HOUR PERIODS USED IN THE "WORST CASE" PSD CALCULATIONS FOR OLYMPIC NATIONAL PARK.

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				27 DECEMBER 1978					
1	285	8.70	696	279	.003	D	.10	.0465	.0665
2	310	9.20	696	278	.003	D	.10	.0465	.0665
3	295	9.20	696	278	.003	D	.10	.0465	.0665
4	275	7.20	696	277	.003	D	.10	.0465	.0665
5	350	4.20	696	277	.003	D	.10	.0465	.0665
6	355	4.00	696	277	.003	D	.10	.0465	.0665
7	10	6.70	220	277	.003	D	.10	.0465	.0764
8	10	9.40	996	277	.003	D	.10	.0465	.0764
9	60	6.30	996	276	.003	D	.10	.0465	.0665
10	190	3.10	996	275	.003	D	.10	.0465	.0665
11	235	4.00	996	276	.003	C	.10	.0735	.1051
12	350	6.70	996	277	.003	D	.10	.0465	.0665
13	355	7.40	996	277	.003	D	.10	.0465	.0665
14	345	7.40	1394	277	.003	D	.10	.0465	.0665
15	355	8.30	1424	277	.003	D	.10	.0465	.0665
16	345	8.30	383	277	.003	D	.10	.0465	.0764
17	345	8.30	367	277	.003	D	.10	.0465	.0764
18	340	7.60	355	276	.003	D	.10	.0465	.0665
19	345	7.80	349	276	.003	D	.10	.0465	.0665
20	350	8.50	295	276	.003	D	.10	.0465	.0665
21	355	6.70	241	275	.003	D	.10	.0465	.0764
22	355	5.40	169	275	.003	D	.10	.0465	.0764
23	15	4.00	169	274	.003	E	.10	.0350	.0501
24	335	2.90	181	274	.003	F	.10	.0235	.0336

TABLE B-8 (CONTINUED)

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				10 JANUARY 1979					
1	295	1.30	87	277	.003	D	.10	.0465	.0665
2	270	2.20	115	277	.003	D	.10	.0465	.0665
3	165	3.10	163	277	.003	D	.10	.0465	.0665
4	300	4.00	211	277	.003	D	.10	.0465	.0665
5	250	5.40	283	277	.003	D	.10	.0465	.0665
6	230	6.30	311	276	.003	D	.10	.0465	.0829
7	230	7.20	331	277	.003	D	.10	.0465	.0829
8	230	5.40	307	277	.003	D	.10	.0465	.0829
9	350	5.80	307	277	.003	D	.10	.0465	.0665
10	340	6.50	293	277	.003	D	.10	.0465	.0665
11	360	6.70	265	277	.003	D	.10	.0465	.0665
12	350	6.70	223	277	.003	D	.10	.0465	.0829
13	350	5.80	228	277	.003	D	.10	.0465	.0829
14	350	3.60	252	277	.003	D	.10	.0465	.0829
15	355	2.20	274	277	.003	D	.10	.0465	.0764
16	355	1.30	336	277	.003	D	.10	.0465	.0764
17	60	1.60	336	277	.003	D	.10	.0465	.0665
18	175	2.50	336	277	.003	D	.10	.0465	.0764
19	175	1.10	113	277	.003	D	.10	.0465	.0764
20	140	1.30	107	277	.003	D	.10	.0465	.0665
21	195	1.10	99	277	.003	D	.10	.0465	.0665
22	210	1.30	107	277	.003	D	.10	.0465	.0665
23	215	2.70	113	277	.003	D	.10	.0465	.0665
24	220	2.50	119	277	.003	D	.10	.0465	.0665

TABLE B-8 (CONTINUED)

HOUR	WIND DIR (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				21 FEBRUARY 1979					
1	15	4.20	169	279	.003	D	.10	.0465	.0764
2	15	6.00	157	278	.003	D	.10	.0465	.0764
3	10	5.60	131	278	.003	D	.10	.0465	.0918
4	10	6.30	115	278	.003	D	.10	.0465	.0918
5	10	6.50	99	277	.003	D	.10	.0465	.0918
6	10	6.00	99	277	.003	D	.10	.0465	.0918
7	10	5.40	99	277	.003	D	.10	.0465	.0918
8	15	5.40	246	277	.003	D	.10	.0465	.0764
9	20	4.50	246	277	.003	D	.10	.0465	.0764
10	25	4.90	246	277	.003	D	.10	.0465	.0764
11	40	4.70	246	277	.003	D	.10	.0465	.0764
12	50	4.20	246	277	.003	C	.10	.0735	.1051
13	65	3.80	246	278	.003	C	.10	.0735	.1051
14	80	3.40	416	279	.003	C	.10	.0735	.1051
15	75	3.10	416	279	.003	C	.10	.0735	.1051
16	75	3.40	468	279	.003	D	.10	.0465	.0665
17	75	3.60	518	279	.003	E	.10	.0350	.0501
18	85	3.60	518	279	.003	E	.10	.0350	.0501
19	150	2.50	191	278	.003	F	.10	.0235	.0336
20	160	1.60	191	277	.003	F	.10	.0235	.0336
21	220	2.00	185	276	.003	F	.10	.0235	.0336
22	200	1.60	163	276	.003	F	.10	.0235	.0386
23	200	1.30	163	276	.003	F	.10	.0235	.0386
24	225	2.20	163	276	.003	F	.10	.0235	.0336

TABLE B-9. THE HOURLY METEOROLOGICAL INPUTS FOR THE 3-HOUR PERIODS CONSIDERED IN THE "WORST CASE" PSD CALCULATIONS FOR OLYMPIC NATIONAL PARK.

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
9 NOVEMBER 1978									
7	10	2.20	101	279	.003	F	.10	.0235	.0336
8	10	3.10	101	279	.003	E	.10	.0350	.0501
9	5	3.10	116	279	.003	D	.10	.0465	.0665
27 DECEMBER 1978									
7	10	6.70	220	277	.003	D	.10	.0465	.0764
8	10	9.40	996	277	.003	D	.10	.0465	.0764
9	60	6.30	996	276	.003	D	.10	.0465	.0665
29 DECEMBER 1978									
10	5	4.20	229	269	.003	D	.10	.0465	.0665
11	5	2.90	464	269	.003	C	.10	.0735	.1208
12	360	3.10	464	269	.003	C	.10	.0735	.1208
15 JANUARY 1979									
10	20	5.40	107	276	.003	D	.10	.0465	.0665
11	20	4.20	91	276	.003	C	.10	.0735	.1051
12	20	4.70	142	276	.003	D	.10	.0465	.0665

TABLE B-9 (CONTINUED).

HOUR	WIND DIR. (DEG)	WIND SPEED (MPS)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV. EL ANGLE (RAD)	STD DEV. AZ ANGLE (RAD)
				25 JANUARY 1979					
7	10	7.60	804	277	.003	D	.10	.0465	.0764
8	10	6.30	972	277	.003	D	.10	.0465	.0764
9	20	4.90	972	277	.003	D	.10	.0465	.0665
				27 JANUARY 1979					
13	15	4.90	157	277	.003	D	.10	.0465	.0829
14	15	6.70	149	277	.003	D	.10	.0465	.0829
15	15	6.00	149	277	.003	D	.10	.0465	.0829
				21 FEBRUARY 1979					
4	10	6.30	115	278	.003	D	.10	.0465	.0829
5	10	6.50	99	277	.003	D	.10	.0465	.0829
6	10	6.00	99	277	.003	D	.10	.0465	.0829
				12 APRIL 1979					
16	355	5.80	2070	283	.003	D	.10	.0465	.0829
17	360	4.50	2070	282	.003	D	.10	.0465	.0829
18	360	3.10	2070	282	.003	D	.10	.0465	.0829

APPENDIX C

SOURCE AND METEOROLOGICAL INPUTS FOR MODEL TESTING

Source Inputs

Section 3 in the main body of the text describes the selection of 20 hours for testing the Cramer, et al. (1975) short-term dispersion model in the Port Angeles area. The model source input parameters were derived from information provided by EPA Region 10, which consisted of a copy of a 15 February 1980 letter from F. H. Royce of ITT Rayonier to G. L. O'Neal of EPA Region 10 and a copy of a 22 April 1980 letter from G. L. O'Neal to B. H. Willis of Environmental Research and Technology, Inc. (ERT). The 15 February 1980 letter was used as the primary data source for the ITT Rayonier Pulp Mill. The 22 April 1980 letter provided average emissions parameters for the Crown Zellerbach Pulp Mill and was also used to estimate the parameters not provided for the ITT Mill in the 15 February 1980 letter.

With the exception of hourly SO_2 emission rates and volumetric emission rates for some of the stacks at the ITT Mill, Table C-1 lists the source inputs used in the model tests. The hourly volumetric emission rates for the two power boilers at the ITT Mill are given in Table C-2 and the SO_2 emission rates for all of the ITT sources except the H. F. Boiler No. 5 are given in Table C-3. The SO_2 emission rate for the H. F. Boiler No. 5 was assumed to be 2.8 grams per second (see Section 2.1). The volumetric emission rates provided in the 15 February 1980 letter for some of the ITT stacks were at standard conditions, which we assumed to be a pressure of 1,013 millibars and a temperature of 289 degrees Kelvin (60 degrees Fahrenheit). The volumetric emission rates at standard conditions were adjusted to the stack exit temperatures for use in the model calculations.

TABLE C-1

SOURCE INPUTS FOR MODEL TESTING

Source	Location*		Stack Height (m)	Stack Exit Temperature (°K)	Volumetric Emission Rate (m^3/sec)	Stack Inner Radius (m)	SO_2 Emission Rate (g/sec)
	UTM X (m)	UTM Y (m)					
(a) ITT Rayonier Sources							
Recovery Furnace	469,790	5,329,250	96.0	300	48.5	1.15	**
Power Boiler No. 4	469,720	5,329,194	35.1	494	**	1.22	**
Power Boiler No. 5	469,718	5,329,183	35.1	444	**	0.84	**
North Bleach Vent	469,758	5,329,184	35.7	286	1.4	0.75	**
South Bleach Vent	469,769	5,329,183	35.4	286	6.0	0.61	**
West Acid Plant Vent	469,753	5,329,185	33.5	288	5.6	0.30	**
H.F. Boiler No. 5	469,698	5,329,165	45.7	336	36.2	1.21	2.8
(b) Crown Zellerbach Sources							
H.F. Boiler No. 8	465,300	5,331,150	36.6	333	22.0	0.90	3.0
Package Boiler	465,300	5,331,150	30.5	480	13.7	0.75	7.9

*The stack base elevation for all stacks was assumed to be 3 meters MSL.
**Rates were variable; see Tables C-2 and C-3.

TABLE C-2

VOLUMETRIC EMISSION RATES FOR THE TWO ITT RAYONIER POWER BOILERS

Case Number	Volumetric Emission Rate (m^3/sec)	
	Power Boiler No. 4	Power Boiler No. 5
1	29.1	0
2	28.3	0
3	28.3	0
4	28.3	0
5	28.3	0
6	22.8	17.4
7	22.8	17.4
8	22.8	17.4
9	19.6	39.7
10	17.5	0
11	17.5	0
12	17.1	6.2
13	24.4	12.8
14	13.8	10.7
15	13.8	10.7
16	13.8	10.7
17	13.8	10.7
18	13.8	10.7
19	13.8	10.7
20	13.8	10.7

TABLE C-3

SO_2 EMISSION RATES FOR SIX OF THE SEVEN ITT RAYONIER SOURCES

Case No.	SO_2 Emission Rate (g/sec)					
	Recovery Furance	Power Boiler No.4	Power Boiler No.5	North Bleach Vent	South Bleach Vent	West Acid Plant Vent
1	20.5	21.7	0.0	0.4	4.6	0.0
2	28.1	21.1	0.0	0.4	2.5	0.0
3	14.1	21.1	0.0	0.4	1.7	0.0
4	15.3	21.1	0.0	0.4	1.3	0.0
5	24.3	21.1	0.0	0.4	1.7	0.0
6	23.0	17.0	24.7	0.4	2.5	0.0
7	23.0	17.0	24.7	0.4	4.2	0.0
8	17.9	17.0	24.7	0.4	5.8	0.0
9	16.6	14.6	56.3	0.0	1.4	0.0
10	19.2	13.0	0.0	0.6	4.2	0.0
11	19.2	13.0	0.0	0.6	4.2	0.0
12	9.2	12.7	8.8	0.8	5.8	0.0
13	20.2	18.2	18.1	0.6	6.6	0.0
14	22.8	10.3	15.1	0.4	6.6	0.8
15	22.8	10.3	15.1	0.4	6.6	0.8
16	22.8	10.3	15.1	0.4	6.6	0.8
17	22.8	10.3	15.1	0.4	6.6	0.8
18	22.8	10.3	15.1	0.4	6.6	0.8
19	22.8	10.3	15.1	0.4	6.6	0.8
20	22.8	10.3	15.1	0.4	6.6	0.8

As discussed in Section 3, an area source with an emission rate of 1 gram per second was used to estimate SO_2 emissions from the black liquor holding pond at the ITT Mill. The Universal Transverse Mercator (UTM) X and Y coordinates of the center of the area source were 470.24 and 5,328.94 kilometers, respectively. The source was arbitrarily assumed to be a 67-meter square, yielding the same approximate horizontal area as the irregularly-shaped holding pond. The characteristic height scale h was assumed to be zero. For each hour, the SO_2 emission rate for the pond was calculated by dividing the estimated contribution of the pond emissions to the observed concentration at the Fourth & Baker monitor by the concentration calculated for the area source with an emission rate of 1 gram per second.

Meteorological Inputs

Table C-4 lists the hourly meteorological inputs for the 20 hours used to test the Cramer, et al. (1975) short-term dispersion model in the Port Angeles area. The inputs were developed following procedures given in Section 2.2.3. The wind direction of 308 degrees is the direction required to transport the centerline of the merged plume from the ITT Rayonier Mill to the Third & Chestnut SO_2 monitor.

TABLE C-4. HOURLY METEOROLOGICAL INPUTS FOR MODEL TESTING

CASE NO	WIND DIR. (DEG)	WIND SPEED (M/SEC)	MIXING DEPTH (M)	AMB. TEMP (DEG K)	POT. TEMP (DEG K/M)	STAB CAT.	WIND EXP.	STD DEV EL ANGLE (RAD)	STD DEV AZ ANGLE (RAD)
1	308	6.70	446	287	.003	D	.10	.0465	.0565
2	308	6.00	270	283	.003	D	.10	.0465	.0565
3	308	6.50	370	287	.003	D	.10	.0465	.0565
4	308	8.50	424	288	.003	D	.10	.0465	.0565
5	308	10.50	466	290	.003	D	.10	.0465	.0565
6	308	10.10	1060	287	.003	D	.10	.0465	.0565
7	308	9.80	1060	287	.003	D	.10	.0465	.0565
8	308	10.30	1060	286	.003	D	.10	.0465	.0565
9	308	7.20	2480	287	.003	D	.10	.0465	.0565
10	308	6.50	712	287	.003	D	.10	.0465	.0565
11	308	8.70	173	286	.003	D	.10	.0465	.0565
12	308	6.30	432	287	.003	D	.10	.0465	.0565
13	308	6.00	1382	291	.003	D	.10	.0465	.0565
14	308	4.00	502	289	.003	C	.10	.0735	.1051
15	308	6.00	516	289	.003	D	.10	.0465	.0565
16	308	7.20	736	290	.003	D	.10	.0465	.0565
17	308	7.20	770	290	.003	D	.10	.0465	.0565
18	308	7.40	986	293	.003	D	.10	.0465	.0565
19	308	8.30	1010	294	.003	D	.10	.0465	.0565
20	308	11.00	1010	293	.003	D	.10	.0465	.0565

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